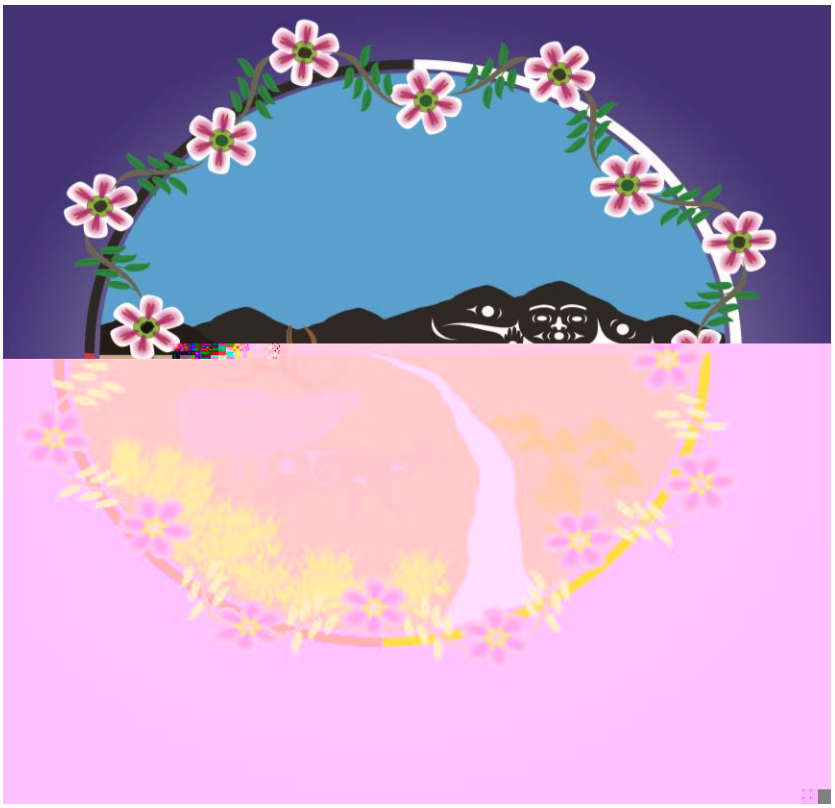
Vulnerability of traditional women's foods, medicinals, and plants used in material culture to climate change on the Olympic Peninsula, WA: Management projections and implications for tribal perspectives on Usual and Accustomed gathering areas



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Final report to
U.S. Geological Survey
Award #G13AC00391

Cover artwork by John Nytom Goodwin (Makah Tribe, Neah Bay)

Artwork explanation, by Gail Woodside

The plant around the border is Prince's Pine and is becoming harder to find. Its relationship for healing and wellbeing weaves its way through the generations of time and space. The squirrel tails plant is declining and as time progresses and change occurs it is no longer a life force for the elk or the people. The ribs are showing on the animals due to habitat loss and poor nutrition caused by changes both anthropogenically and climatically. The sky is blue denoting absence of clouds and rain, giving a false sense of acceptance. The mountains are without snow denoting that the coming change in temperature and precipitation is imminent. The people are looking out into the landscape to seek what they have gathered since time immemorial. They have always looked out into the landscape, but what they are seeing is that as change occurs what they are looking for escapes their vision. The mountain is also looking to see if it can locate what the people are seeking; its wisdom can offer no stories. The medicine wheel shows cross cultural ties between my ancestry and the ancestry of the S'Klallam people. The medicine wheel also tells a story of change, as it does not just stay in one location but travels across the landscapes to all people who are from the mother and changes their way of life as well.

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We would like to thank the Port Gamble S'Klallam Tribe for their welcoming kindness and generosity making this project a reality and allowing a partnership and collaboration to be formed with Oregon State University to accomplish this good work. We want to thank Tribal Chairman Jeromy Sullivan and the Tribal Council for all of your support during this stage of the project and to completion of other projects currently being finished. We also wish to thank PGST CEO Kelly Sullivan, Natural Resources Director Paul McCollum, Cultural Poaervrtnth alsi9(ourrKelly)] TJET

1 ADMINISTRATIVE

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Project title: Vulnerability of traditional women's foods, medicinals, and plants used in material culture to climate change on the Olympic Peninsula, WA: Management projections and implications for tribal perspectives on Usual and Accustomed gathering areas

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2 PUBLIC SUMMARY

This short-term project responded to concerns about the disappearance of culturally important plants in traditional gathering areas expressed by elders of the Port Gamble S'Klallam Tribe (PGST) (Olympic Peninsula, WA), both currently and in response to continuing climate change.

A formal Memorandum of Understanding was developed between OSU and the PGST to guide this culturally sensitive research. We recommend this formal approach to researchers considering tribal partnerships in order to ensure expectations of all parties are clearly outlined.

During formal interviews and informal conversation, PGST elders mentioned 37 plants, of which eight terrestrial species and a group of marine taxa were of particular concern due to limited availabilities in 26 traditional gathering locations within the Usual and Accustomed (U&A) gathering area guaranteed by the 1855 Point No Point Treaty.

Landsat data were used to analyze recent changes in land cover within the U&A. Substantial changes in land cover were found between 1975 and 2010. Detailed analysis for 1990-2010 documented recent forest fragmentation, loss of freshwater wetlands, and both losses and gains of saltwater wetlands. Current regional distribution and autecological information for the eight focal terrestrial species were compiled using available databases, herbarium records and literature. Field studies documented plant communities in which selected focal species are currently found.

Downscaled results from existing PNW climate scenarios were adapted to the Olympic and Kitsap Peninsula, which house the U&A. These suggest somewhat hotter, drier summers and somewhat warmer, wetter conditions in other seasons by the late 21st century. Likely changes in seasonal precipitation were less clear, with uncertainty about the magnitude and even direction of change. Published information related to climate variables for the eight focal species was sparse, making even semi-quantitative projections of response to changing climates impossible. In addition, we created map of the U&A shoreline representing expected changes in shoreline due to changing climates combined with tectonic events.

In summary, this project established a baseline on which future studies of vulnerable traditional women's plants can be built.

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4 PURPOSE AND OBJECTIVES

Our purpose was to respond to concerns expressed by elders of the Port Gamble S'Klallam Tribe about shrinking availability of a short list of plants of key cultural concern. In order to do so, we needed to understand which plant taxa are of particular cultural concern, and to develop a way of collaboratively reducing what we expected would be a fairly long list of plants to a few key taxa about which we could provide scientific information related to climate sensitivity. As part of this research we used Landsat-based imagery to document recent (~40 year) landscape change and created downscaled climate scenarios specific to the PGST Usual and Accustomed gathering area (U&A) established by the 1855 Point No Point Treaty. Our intention had been to facilitate the tribal development of a set of management options to address shifting ranges and abundances of prioritized species. However, for reasons related to the pace at which this research unfolded, this last objective proved to be beyond the scope of this short research project.

5 ORGANIZATION AND APPROACH

5.1 Background

Lisa Lone Fight, the Mandan/Hidatsa/Sahnish indigenous researcher whom we retained for the land use change part of this research, eloquently summarizes the background for this and similar studies (Lone Fight 2014):

> "*Indigenous people of the Western Hemisphere have lived in close relation to the land throughout their history. Knowledge of land change has been a necessary preoccupation for those who seek to survive and thrive in a sustainable manner. While issues of sustainability can be debated it is beyond doubt that the last two to three hundred years have seen unprecedented Land Use/Land Cover Change (LUCC). The advent of large scale commercial fishing and "pioneer" agriculture as well as continuous intrusion from urban population centers has accelerated this change in an historically unprecedented manner and scope. Every system, resource, species and land type is now affected. The salmon have retreated along with uncounted other species of plants and animals. New invasive species have taken hold and sometimes supplanted the indigenous species.*
>
> *"There are few areas where the nature of this change is more apparent or complex than the land base(s) of Native American nations1*[1]*. Native*

[1] *While the term "reservations" is often used when discussing Native American lands, it is loosely descriptive and does not include the multiple categories of lands owned by, under the jurisdiction of or held in trust for Native nations. The term "land base" will be used in preference with the other term reserved for specific use in context.*

> *Americans, the indigenous caretakers of coastal ecologies, have seen their life ways change dramatically and their land management influence contract to geopolitically defined tribal areas that are "reserved" or secured via treaty, agreement, purchase and policy for their use[2]. The remaining lands lying under the direct influence of Native Nations are often a patchwork of jurisdictions where land use is frequently dictated by complex and often conflicting local, tribal, state and federal policies. The situation is further complicated by differing Euro-American and indigenous conceptions of "land". The two systems often diverge when considering what constitutes and defines the living and non-living world, the place of human beings in the environment, the definition of "ownership" and the perceptions and understandings of what the term "land" entails. The effects and "politics" of poverty, state involvement, direct federal control and tribal sovereignty provide additional layers of complexity that form barriers to (or sometimes provide resources for) understanding rapid LUCC."*

The people for and with whom this present research was done are the Port Gamble S'Klallam Tribe (PGST), who are known as "NUX SKLAI YEM" or the "Strong People." Today, the people are asking what they should learn from their ancestors to be able to understand the problems that develop in today's world and how to prepare for the future (DeCoteau and Waterhouse 2013). DeCoteau and Waterhouse state:

> *"It has been said that mankind is incapable of learning from the past. This may be true for western or white society, but it is not true for Native American people. The very essence of our traditional culture demands that knowledge acquired in the past be passed on to each succeeding generation by the elders of the time. In this manner our culture has survived many years of oppression and social change."*

For these reasons we came to the elders to discuss their concerns for future change, to preserve oral traditions and ways of knowing, and to understand how to implement this knowledge to help educate the future generations.

Specific concerns have been expressed by elders and cultural coaches in regard to preserving and/or restoring cultural lifeways. Across the Pacific Northwest tribal people have come together to discuss and direct research and preserve knowledge. It is here that building relationships with western scientists and traditional people come together to figure out ways to preserve and prepare.

[2] *It is important to note that reservations are often populated by both Native American and non-Native American groups and landowners.*

5.1.1 Study Area

Lone Fight (2014) discusses the Port Gamble S'Klallam Tribe (PGST) reservation and explains its relationship to the Point No Point Treaty (Usual and Accustomed) area. She notes that the PGST reservation consists of approximately 1700 acres of land held in trust by the federal government. There is no private land ownership on the reservation. Most of the land is forested with residential businesses and office areas. The reservation receives approximately 20 inches of rain per year due to its location in the Olympic Mountain Range shadow. The reservation lands rise from the beach to a gently rolling terrain. There are deer and other wildlife on reservation. The tribe has acquired three pieces of land that are adjacent to the reservation. The major piece, nearly 400 acres, is primarily forested, with some young trees planted a few years ago (Lone Fight 2014, PNPTC 2015).

At the same time, Lone Fight notes that the tribe has reserved the right to harvest in its usual and accustomed areas, which are much larger than the reservation itself (see e.g. Figure 1). She goes on to quote the Treaty of Point No Point:

> *"The right of taking fish at usual and accustomed grounds and stations is further secured to said Indians, in common with all citizens of the United States: and of erecting temporary houses for the purposes of curing; together with the privilege of hunting and gathering roots and berries on open and unclaimed lands. Provided, however, that they shall not take shell-fish from any beds staked or cultivated by citizens"*- Treaty of Point No Point, Jan 26, 1855

Figure 1. Point No Point treaty area (Usual and Accustomed Area) and Port Gamble S'Klallam reservation. Source: PNPTC 2015

5.1.2 Approach

Our approach to this research was in two stages. On the one hand, we used a combination of individual and small group interviews with tribal elders and plant Cultural Coaches to document traditional gathering areas as well as the identity and distribution (past and present) of species of cultural concern. On the other hand, we used conventional scientific tools (change analysis from remote sensing products, climate scenarios, vegetation field studies, review of scientific literature) to document past changes as well as potential future climate-related changes in the distribution of plants of key cultural concern within the Usual and Accustomed (U&A) gathering areas determined by the 1855 Point No Point Treaty.

5.2 Memorandum of Understanding

A formal Institutional Review Board process was engaged through the Oregon State University IRB Office to ensure that protection of interviewees and their rights were maintained during the interview process. The preparation of the IRB application included discussions with the PGST's Administration, Natural Resource Office, and Cultural Preservation Office. The OSU team was given expedited review from the OSU IRB Office, and the project was approved October 30, 2013.

At the same time, however, the Port Gamble S'Klallam Tribe (PGST) and the researchers at Oregon State University (OSU) also discussed tribal concerns at length, including how best to identify issues in "Usual and Accustomed" (U&A) areas. A formal MOU process structured the shared goals, expectations, and commitments as brought forth by the PGST and its Natural Resource Office and Cultural Resource Office in partnership with OSU researchers. The resulting MOU (Appendix I) formulated objectives regarding sensitive local knowledge, how that knowledge would be protected, how collected data and photographs would be stored, and how to archive this information for the Cultural Preservation Office. The MOU also outlined how to disseminate information through tribal authority. Discussing and creating an MOU identified the starting point in approaching tribal elders and in understanding epistemology and cultural protocol, and was an important step in building relationship and trust between the OSU investigators and the PGST.

The study and the MOU were approved by the Tribal Chairman Jeromy Sullivan, Tribal CEO Kelly Sullivan, Tribal Cultural Preservation Officer Marie Hebert, and Tribal Natural Resource Officer Paul McCollum.

5.3 Interviews

5.3.1 Prior research by Central Washington University

Prior to speaking with elders, interviews with PGST elders were conducted in 2010 by Central Washington University. The PGST Natural Resources Office gave OSU permission to review these interviews. In this study, elders had been interviewed regarding cultural lifeways past and present; most questions related to natural resources and subsistence gathering. Elders were asked questions about historical subsistence gathering including fish, shellfish, ducks and other birds, deer, elk, seals, and plants. Interviews also focused on noting changes in resources as well as the management of current resources.

In reviewing the transcripts with PGST Cultural Coach Mary Jones, a pattern was noticed wherein specific gathering locations of plants of key cultural concern were incomplete or not discussed either by the elders or the researchers themselves, while great detail for other resources was included. Woodside and Jones found this issue to persist throughout the entire set of CWU transcripts. Further, the CWU interviews did not provide specific information for species gathered by elders and other tribal members of the PGST (e.g., seasonality and gathering locations).

Based on the CWU research, Woodside and Jones identified a stream of questions for elders regarding plants in the Usual and Accustomed subsistence gathering areas. Using these questions they explored elder insights pertaining to (1) forests, (2) tidelands and wetlands, and (3) terrestrial animal/fish/bird associations. The results were used to structure further botanical research using conventional scientific approaches.

<u>5.3.2 OSU interviews</u>
Elder interviews were conducted by Gail J. Woodside with the assistance of PGST Cultural Coach Mary Jones between the months of April and June 2014 and beginning again in October 2014 through the end of January 2015. Interviews were intermittent due to severe personal injury of the researcher and loss of family members, not only for the researcher herself but also for that of the PGST Cultural Coach, Mary J. Jones.

Elder interviews began with written invitations to selected elders to attend a Focus Group, based on information that had been provided in previous interviews conducted by Central Washington University (CWU) between 2010 and 2012. The focus group was held May 7, 2014. Dinner was served and a presentation was given by Gail J Woodside and Mary J. Jones. Twelve elders (including Mary Jones) were in attendance.

During the focus group elders were served a meal, paid a stipend, and were gifted with traditionally made jewelry by a tribal artist. Some elders who attended spoke about concerns regarding elk and other bits of information; however the purpose of the Focus Group was to identify what researchers and tribal members knew about subsistence locations that were identified during the CWU interviews and to introduce how the OSU research study would proceed.

Personal interviews with elders were by personal invitation only; elder’s interviews were arranged around their schedules. Elders were given an overview of the study as well as a list of questions that were approved by the Tribal Natural Resource Office and OSU’s Institutional Review Board. The interviews were conducted at several places including but not limited to the Cultural Preservation Office, The House of Knowledge, Elder Homes, or Elders Offices or place of work (carving shed). One Elder interview occurred in the field.

A map was shown to elders at all interviews. The map was created based on knowledge of plant locations as established from past interviews and the NUX SKLAI YEM S'Klallam history document (DeCoteau and Waterhouse Jr. 2013). This map was used for all interviews to orient the elders on the landscape; in some cases elders were asked to point out specific locations of plants historically gathered to narrow previously discussed locations in past interviews. The map also identified the boundaries of the usual and accustomed gathering areas and also outlined Olympic National Park. Use of the map gave the PGST and OSU research team a better sense of traditional and contemporary gathering locations to be revisited. This map provided great assistance in locating sites in the field.

Elders were given the choice to be audio recorded, video recorded, or to have notes taken by the researcher; they could also agree to any combination of these. Photo agreements were approved by all elders to be taken at a later time. Elders were paid a stipend, given a traditionally made give-a-way, and received personally ordered homemade pies or lunch. Bottled water was always provided for elders if needed. Consent forms were signed by all elders, and a list of signatures were kept for receipt of handshake money (stipend). The list of questions for interviewees is given in Table 1.

Table 1. List of questions for interviews.

Generic:
Do you have any questions that can I answer for you about this interview?

Forest Plants/Shrubs/Trees:

1. Which forest plants of key cultural significance do you think are the most important?
2. Are these plants that were historically used?
3. Are these plants used today?
4. In which season(s) are these plants used/gathered the most?
5. In what location(s) have you seen these plants?
6. Can you point the location(s) out on a map?
7. What contributions do these plants give to your tribal community?
8. What is your biggest concern regarding these plants?
9. Are you noticing a reduction in significant plants? If so, which ones?
10. Why do you think there is a reduction in these significant plants?
11. Are you noticing an increase in significant plants? If so, which ones?
12. Why do you think these significant plants are increasing?
13. Do you notice anything unusual about any of these plants?
14. Are there any historical/contemporary plants that are no longer available?
15. Why do you think they are no longer available?

Forest Plants/Shrubs/Trees (continued):

16. Have you noticed any plants that normally would never be in these locations or any new plants?
17. What else would you like to add?

Tidelands and Wetlands Plants/Shrubs/Trees:

1. Which plants located in the tidelands of key cultural significance do you think are the most important?
2. Are these plants that were historically used?
3. Are these plants used today?
4. In which season(s) are these plants used/gathered the most?
5. In what location(s) have you seen these plants?
6. Can you point out the location(s) on a map?
7. What contributions do these plants give to your tribal community?
8. What is your biggest concern regarding these plants?
9. Are you noticing a reduction in significant plants? If so, which ones?
10. Why do you think there is a reduction in these significant plants?
11. Are you noticing an increase in significant plants? If so, which ones?
12. Why do you think there is an increase in these significant plants?
13. Do you notice anything unusual about these plants?
14. Are there any historical/contemporary plants no longer available?
15. Why do you think that they are no longer available?
16. Have you noticed any plants that normally would never be in these locations or any new plants?
17. What else would you like to add?

Plant/Shrub/Tree/Animal Associations:

1. Which plants of key cultural significance are important to wildlife/fish?
2. Which wildlife/fish species utilize these plants?
3. Are the wildlife/fish that use these plants/shrubs/trees of key cultural significance?
4. Have these plants always been utilized by wildlife/fish?
5. In which season(s) are these plants utilized by wildlife/fish?
6. How were the weather conditions when you saw the wildlife/fish?
7. What time of day/night did you see wildlife/fish utilizing plants?
8. What is your biggest concern about the availability of these plants for wildlife/fish?
9. If these plants are not available do you think there will be an increase or decrease in wildlife or fish?

Plant/Shrub/Tree/Animal Associations (continued):
10. Are any of these plants utilized by traditional tribal gatherers and wildlife/fish at the same time?
11. Are any of these plants utilized by traditional tribal gatherers and wildlife/fish in different seasons?
12. Do any of the plants that wildlife/fish utilize increase or decrease plant abundance for gatherers?
13. If the wildlife/fish were not utilizing these plants, do you think they would be more available for gatherers? Less available?
14. Where (location) in the usual and accustomed gathering/fishing locations do wildlife/fish utilize these plants?
15. Can you point out the location on a map?
16. What else would you like to add?

5.4 Conventional scientific approaches

5.4.1 Recent changes in land cover on the Olympic and Kitsap Peninsula (L. Lone Fight)

[Note: We retained Lisa Lone Fight (Mandan, Hidatsa, Sahnish indigenous scientist and remote sensing researcher, Spatial Sciences Center, Montana State University) to investigate recent Land Use/Land Cover Change (LUCC). The portions of this report discussing recent changes in cover use Lone Fight's (2014) organization and wording almost verbatim.]

This project used remote sensing and ground truth as methods of documenting and analyzing the rate and scope of LUCC on the Usual and Accustomed Areas outlined in the Point No Point Treaty and tribal land base of the Port Gamble S'Klallam people. USGS Landsat and aerial ortho-rectified images of areas of known current or historic traditional women's plant growth were compared using community accessible web-based software analysis tools to produce change maps and other useful products. These maps and other products were then correlated to ground truthed photographs/transects collected during the project.

Primary data for this analysis came from Landsat Thematic Mapper. Landsat Thematic Mapper (TM) data are acquired from the Landsat series of commercial satellites operated by NASA. Since first available in 1984, data have been used to map a variety of land cover types, including forested lands, agriculture, snow packs, and geologic formations and structure. The spatial resolution of TM data is 30 meters by 30 meters.

The spectral resolution of Landsat TM data refers to the positioning of the sensor's seven spectral bands in relation to the reflected visible and infrared wavelengths of the electromagnetic spectrum. Band six, designed to capture data reflected from the thermal wavelengths of the electromagnetic spectrum, was not used in this study. Data used in this study were collected between 1975 and 2010.

In an effort to create capacity within the community a number of open source and web-based tools were used in this analysis. These include SAGA GIS, QGIS Brighton, Change Matters by ESRI, Google Earth, USGS Eros Data Sets and the NOAA C-Cap Land Cover Atlas. These were chosen because of the need for a community participatory model that empowers indigenous communities. Traditional remote sensing software is prohibitive both in licensing expense and in the training necessary to utilize it and it was felt that the use of these tools was within the capacity of community members involved in the project to duplicate.

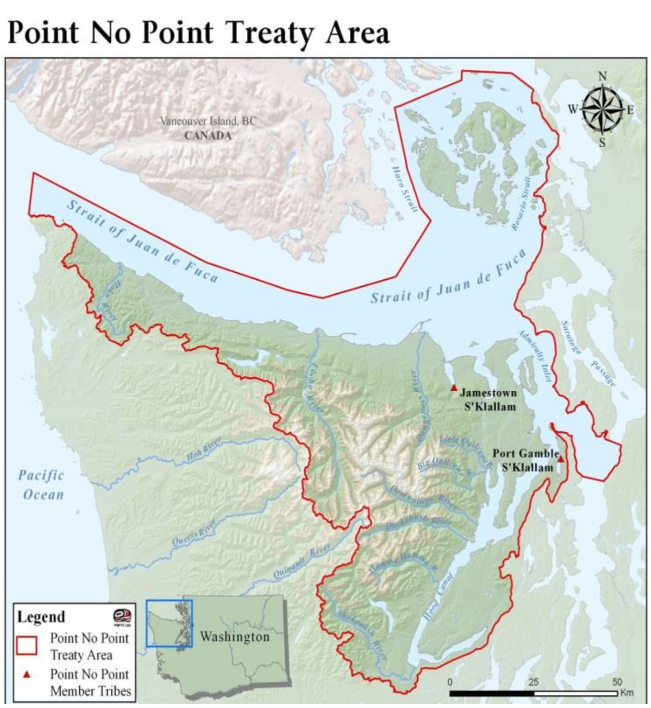
Lone Fight, PGST Cultural Coach Mary Jones, and Jesse Ford conducted a site visit August 6-7, 2014 to ground truth remote sensing information. Numerous traditional women's plants were observed in the company of Ms. Jones. While there were clearly plants of significant importance value, it became clear that limitations of pixel size and canopy cover made remote-sensing impractical for direct observation of change in these plant communities. However, since many of these communities are associated with forests or particular species of trees, wetlands and canopy, change effects may be inferred from observed changes in these classifications.

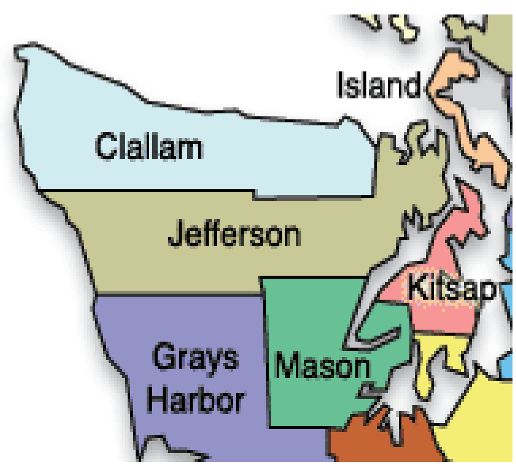
5.4.2 Focal plant species

5.4.2.1 Current distribution

The USDA PLANTS database (USDA, NRCS 2015) was used as a source of general information about current distribution of focal species. We also consulted the Consortium of Pacific Northwest Herbaria (CPNH 2015), which maintains records for the PNW from 33 participating herbaria. Both PLANTS and the CPNH display records aggregated to the county level; the Point No Point Treaty Area includes portions of four counties (Clallam, Jefferson, Mason, and Kitsap) (Figure 2).

Figure 2. Maps of the Point No Point Treaty Area and counties of the Olympic and Kitsap Peninsulas, Washington. Sources: PNPTC 2015 and County Maps of Washington 2015.





5.4.2.2 Catalogue of ecological data

Autecological information for focal plant species was harvested by searches in various databases, including Agricola, CAB Abstracts, Google Scholar, ProQuest, Environmental Science and Pollution Management, TreeSearch, Web of Science, and Wildlife and Ecology Studies Worldwide. These searches focused on information regarding climate tolerances and sensitivities, particularly temperature and precipitation.

5.4.2.3 Field work

A small field component involving vegetation surveys was included in our original research plan in order to (1) document frequency and/or abundance of focal species in traditional gathering areas and (2) to understand at a coarse level the composition of existing plant communities hosting focal species. Traditionally, both frequency/abundance and the composition of existing plant communities hosting focal species were well known to Cultural Coaches. However, profound changes in the U&A related to widespread clearcutting, widespread land conversion to residential, commercial, industrial, and military purposes, road construction (and consequent edge effects), and so forth have diminished or destroyed many traditional gathering areas and created potentially novel habitats in others.

After preliminary reconnaissance of traditional gathering areas to which we were permitted access, we combined these two objectives in order to describe the situation in which focal species currently exist. Seven areas were identified in which one or more focal species were found. Sampling sites were determined by locating plants of key cultural concern within usual and accustomed locations. Plants that were located on tribal reservation lands were noted for tribal use, but specific data on reservation lands was not necessarily gathered. Rare or hard to find plants are not necessarily located on reservation lands or are no longer gathered due to concerns or because they no longer exist due to anthropogenic change on reservation landscapes. Locations were recorded and notes were made on traditional sites at which focal species did not currently exist in order to help initiate tribal plant restoration projects.

A semi-quantitative phytosociological method (the relevé, Mueller-Dombois and Ellenberg 1974), combined with Rangeland Health procedures (Pyke et al. 2002, Pellant et al. 2005), was used to characterize plant associations and document habitats in which focal species were present. Site locations were recorded using GPS as well as to record locations and counts of individual specimens of focal plant species. Neither site locations nor individual specimens were marked in a way that could be easily recognized. This ensured that locations of plants were protected and locations in which data were collected cannot be visually identified. This procedure met responsibilities set forth in the MOU. GPS coordinates and plant counts were recorded on field forms. Field forms also included a drawing of the area where plants were located, lists of associated plants, soil data, directional orientation, slope, elevation, spherical densitometer models of canopy cover, forest layout, snags, legacy trees, geographic features, and other identifying anthropogenic additions to the landscape such as power poles, mail boxes, easements, buildings, roadways, and fences. Photographs were also taken to identify and catalogue plants, plant parts, and lay of landscape for mapping and other uses. Only the phytosociological data are discussed in this report.

Maps were created for the final report to USGS showing large landscape views identifying zones where certain plants may be located. Maps generated do not show plants, plant locations, or sampling sites. Maps are general locations labeled with highlighted swaths of color denoting the zone in which plants may be located. Two maps are of traditional gathering areas. These traditional areas were very hard to identify due to scarcity of plants still in traditional locations. The other rare or hard to locate plants are not mapped as they were not located or are no longer easily accessible due to rarity.

5.4.3 Climate change

For the purpose of this report, we focus on two aspects of climate change that will likely affect both the distribution and abundance of culturally important plant species: (1) factors related to changes in temperature and precipitation affecting terrestrial environments, and (2) changes in sea level. It is beyond the scope of this small project to look at potential hydrological changes resulting from combinations of these factors, although this would be a highly desirable direction for futures research.

5.4.3.1 Temperature and precipitation scenarios (D. Sharp)

Temperature and precipitation scenarios were developed by Darrin Sharp (Oregon Climate Change Research Center, Oregon State University). Multi-state regional projections generated for the Pacific Northwest by Mote and Salathé (2010) were used as a reference. The Multivariate Adaptive Constructed Analogs (MACA) statistical downscaling method of Abatzoglou and Brown (2011) was used as a source for the climate projections contained herein. This method downscales the model output from a suite of GCMs of the Coupled Model Inter-Comparison Project v5 (CMIP5) for the historical period (1950-2005) and the future (2006-2100), using two marker emissions scenarios (where RCP4.5 is the "low", and RCP8.5 is the "high" scenario) (IPCC 2008). The GCM outputs were downscaled from their native resolution to 6 km resolution. The domain for this analysis was the Olympic and Kitsap Peninsulas (explicitly, 47.00- 48.40 N and 235.25 - 237.50 E). Only data points over land were considered. Results of 18 GCMs were included.

The following climate parameters available from MACA were analyzed:

1. total monthly precipitation;
2. mean monthly maximum temperature;
3. mean monthly minimum temperature; and
4. mean monthly temperature (calculated as the average of monthly maximum and minimum temperatures).

All parameters were aggregated seasonally (winter, spring, summer, and fall). Scenarios for two time periods were examined: mid-century (2040-2069) and late century (2070-2099).

5.4.3.2 Likely changes in sea level

Rising sea levels from melting continental ice, combined with the thermal expansion of water in a warming climate, can be offset to some extent by tectonic changes, including continued uplift following the loss of continental ice during the last full glacial period. According to Mote et al. (2008), there is a potential for a net *decrease* in observed sea level in some locations on the Olympic Peninsula; more recently, however, Reeder et al. (2013) reported central estimates of year 2100 sea level rise projections (relative to 2000) of 61 cm in on the NW Olympic Peninsula and 62 cm for Puget Sound. These estimates combine climate scenarios and likely tectonic changes. Any rise in sea level will of course be amplified during storm surge events. We constructed a map of the shoreline of the Usual and Accustomed area using the two foot Digital Elevation Map contour to estimate land loss in U&A coastal environments.

5.4.4 Plant responses to changing climate

Once the short list of plants of particular cultural concern had been developed and current distributions investigated using the USDA PLANTS database (USDA, NRCS 2015) and the Consortium of Pacific Northwest Herbaria (CPNH 2015)(Section 5.4.2.1), we also used herbarium records to document the earliest representation of each species in the four-county area that includes the U&A. Literature reviews for climate-related information for each species were performed using numerous search terms in Agricola, CAB Abstracts, Google Scholar, ProQuest, Environmental Science and Pollution Management, TreeSearch, Web of Science, and Wildlife and Ecology Studies Worldwide (Appendix 2). The intention was to use climate scenarios in combination with autecological data to estimate likely changes in distribution of focal species.

6 PROJECT RESULTS

6.1 Interviews

Arranging the Focus Group helped establish importance and interest in this study. Twelve elders in the Focus Group (including Mary Jones) were in attendance; some elders interviewed by CWU were present at the OSU Focus Group, but did not speak during this time (Table 2).

During the presentation, discussions were concentrated specifically within the Usual and Accustomed gathering areas (U&A) regarding plants of key cultural concern. Elders expressed their concerns about what had been observed recently in the traditional gathering areas and also regarding plants that are becoming rare and extremely hard to find. Elders were also informed that information gathering would assist in educating the generations but would also include education regarding the different types of plants that are of key cultural importance. Discussion also suggested that at study completion, the next phase could include Jamestown S'Klallam and Elwha S'Klallam people who may want to share their knowledge to leverage information that can be shared to protect plants and plant locations.

During individual interviews, elders expressed concerns about plants of key cultural concern, shared traditional knowledge regarding these plants, and specified some traditional gathering locations for individual plants. Elders discussed use of plants, how plants were broken down from their natural state to be utilized for specific reasons, and frustrations about access to plants (either access to properties or scarcity of plants).

Table 2 summarizes all interviews done and/or reviewed in the course of the OSU research, the relationship between the OSU and the CWU studies, and the nature of available documentation. Elder Identity Codes represent elders who attended the OSU Focus Group or were personally interviewed by OSU Researcher Gail J. Woodside and Cultural Coach Mary Jones.

6.1.1 Plant species of concern

Cultural lenses complicate ethnobotanical studies. Indigenous taxonomies do not map in a one-to-one fashion onto the culturally specific taxonomy reflected in Linnaean classification. This is hardly surprising, because Linnaean taxonomies are constructed to reflect scientific understanding of evolutionary relationships whereas Indigenous taxonomies represent connectivity and generational uses, including seasonality, synthesis, commonality with other plants, and techniques (among other things). To further complicate the matter, each taxonomic approach has “lumpers and splitters”.

In the absence of researchers specifically trained in both methods, the only way to really understand how taxonomies correspond is for practitioners trained in each approach to spend significant time in the field together, discovering what is and isn’t included in the particular socially constructed definitions of the taxa of interest. In this sense, this brief project was not, and in fact could not be, constructed as an ethnobotanical study. Therefore, more taxonomic research is probably needed in at least some cases in order to have an accurate understanding of the Linnaean identity of species recorded in Table 3. For these reasons, the Linnaean designations for taxa in Table 3 should be regarded as provisional; this in turn affects all the material in this section of this report.

Our initial proposal called for a focus on ten taxa that could be characterized as plants of “key cultural significance”. The number was chosen arbitrarily; it represented an estimate of how many individual taxa could really be considered in a scope of effort of this magnitude. As it turned out, it was not possible to rank the plants discussed in order of cultural importance, because all plants mentioned are culturally important. What we heard clearly, however, was that the steadily decreasing availability of several taxa has been profoundly unsettling to elders and traditional users. Consequently, species were ranked as rarest or most difficult to find to most abundant on the U&A and tribal reservation lands (Table 3). There were nine taxa in this situation, one of which was a group of marine species generally referred to as “seaweed”. For our literature review we focused on the eight remaining species that were of particular concern due to their diminished availability in traditional gathering areas.

Table 2. Port Gamble S'Klallam Tribe elders/Cultural Coaches interviewed. Names of interviewees are omitted from this USGS report in accordance with the requirements of the MOU as well as for reasons of privacy.

OSU Elder Identity Code	OSU Focus Identity Code	OSU Interview Identity Code	CWU Interview	CWU Notes	OSU Interview	OSU Audio	OSU Video	OSU Notes
1	50714-1	60714-1	YES	X	YES	X	X	X
2	50714-2	NA	YES	X	NO	X		X
3	50714-3	60414-3	YES	X	YES	X		X
4	50714-4	60314-4	NO		YES	X		X
5*	NA	NA	NO		NO			
6	50714-6	60314-6 60514-6	NO		YES	X	X	X
7	50714-7	011315-7	NO		YES	X	X	X
8	50714-8	011315-8	NO	X	YES	X	X	X
9	50714-9	60514-9 60614-6	YES	X	YES	X	X	X
10	50714-10	60715-10	YES	X	YES	X	X	X
11	50714-11	NA	YES	X	NO	X		X
12	50714-12	NA	NO		NO	X		X
13	50714-13	060614-13	NO		YES	X	X	X
14	NA	011315-14	NO		YES	X		X
15	NA	NA	YES	X	NO			
16	NA	NA	YES	X	NO			
17	NA	NA	YES	X	NO			
18	NA	011315-18	NO		YES	X		X
19	NA	NA	YES	X	NO			
20	NA	061514-20	NO		YES	X		X

Elder #5 was not interviewed by CWU, but was part of the OSU focus group. However, this person did not speak in the focus group, so there are no audio or written notes. This person was not individually interviewed by OSU

Table 3: Culturally important plant taxa. The eight focal species are highlighted in yellow. Five entries were ranked as equally important (Importance =19); taxa listed after that were only mentioned in informal conversation, and therefore not ranked.

S'Klallam Common Name	S'Klallam Name	Common Name	Linnaean Classification	Family	Importance (by Scarcity)	Easily available in traditional locations?
Sxusem Berries	sx̣ʷásəm	Soapberry, Buffaloberry	*Shepherdia canadensis* (L.)Nutt.	Elaeagnaceae	1	no
Prince's Pine		Prince's pine	*Chimaphila umbellata* (L.) W.P.C. Barton	Pyrolaceae	2	no
Yew	ƛ̓əŋ̓q̓áɬč	Pacific yew, Western yew	*Taxus brevifolia* Nutt.	Taxaceae	3	no
Seaweed		seaweed, wireweed	*cf. Sargassum muticum?*		4	no
Cedar	x̣páy; x̣paʔčíɬč; x̣paʔyáɬč; x̣paʔyíɬč; x̣páʔčɬč	Western Redcedar	*Thuja plicata* Donn. ex D. Donn	Cupressaceae	5	no
Devil's Club	púʔqʷɬč	Devilsclub	*Oplopanax horridus* (Sm.) Miq.	Aliaceae	6	no
Squirrel Tail		Common Yarrow	*Achillea millefolium* L.	Asteraceae	7	no
Cattail	kʷúʔət	Common cattail	*Typha latifolia* L.	Typhaceae	8	no
Cascara		Cascara	*Frangula purshiana* (DC.) A. Gray	Rhamnaceae	9	no
Ironwood	q̓áʔc̓ɬč	Oceanspray	*Holodiscus discolor* (Pursh) Maxim.	Rosaceae	10	yes
Red huckleberry	píxʷ	Red huckleberry				

S'Klallam Common Name	S'Klallam Name	Common Name	Linnaean Classification	Family	Importance (by Scarcity)	Easily available in traditional locations?
Salmonberry	ʔəlíluʔ	Salmonberry	*Rubus spectabilis* Pursh	Rosaceae	15	yes
Thimbleberry	t̕ə́qʷəm	Thimbleberry	*Rubus parviflorus* Nutt.	Rosaceae	16	yes
Nettles	sčx̣áyč; c̕c̕č̕x̣áɬč	Stinging nettle	*Urtica dioica* L.	Urticaceae	17	yes
Plantain, elephant ears		Plantain	*Plantago major* L.	Plantaginaceae	18	yes
Blackberry	sq̕ʷəyáyŋxʷ	Himalayan Blackberry	*Rubus armeniacus* Focke	Rosaceae	19	yes
Red alder	sqʷúŋəɬč	Red alder	*Alnus rubra* Bong.	Betulaceae	19	yes
Solomon's seal		Little false Solomon's Seal, false lily of the valley	*Maianthemum stellatum* (L.) Link	Liliaceae	19	yes
Vine maple		Vine maple	*Acer circinatum* Pursh	Aceraceae	19	yes
Western hemlock		Western hemlock	*Tsuga heterophylla* (Raf,) Sarg.	Pinaceae	19	yes
Beargrass	ƛ̕ə́ƛ̕	Common beargrass	*Xerophyllum tenax* (Pursh) Nutt.	Liliaceae	-	-
Blueberry	ŋə́ci̓ʔnəč	Blueberry	*Vaccinium spp.*	Ericaceae	-	-
Eelgrass	táməx̣	Common eel-grass, Seawrack	*Zostera marina* L.	Zosteraceae	-	-
Kelp					-	-
Wild onions		Nodding onion, Wild onion	*Allium cernuum* Roth	Liliaceae	-	-
Oregon grape		Oregon grape, Cascade barberry	*Mahonia nervosa* (Pursh) Nutt.	Berberidaceae	-	-
Salal	t̕áqaʔ	Salal	*Gaultheria shallon* Pursh	Ericaceae	-	-
Sweetgrass		Sweetgrass, vanillagrass	*Hierochloe odorata* (L.)P.Beauv.	Poaceae	-	-
Tule		Tule	*Schoenoplectus acutus* (Muhl. Ex Bigelow) Á. Löve & D. Löve	Cyperaceae	-	-
Wild potatoes		Small camas	*Camassia quamash* (Pursh) Greene	Liliaceae	-	-

S'Klallam Common Name	S'Klallam Name	Common Name	Linnaean Classification	Family	Importance (by Scarcity)	Easily available in traditional locations?
Wild rose		Nootka rose, Wild rose	*Rosa nutkana* C. Presl	Rosaceae	-	-
Wild strawberry	t̓éʔyəqʷ	Wild strawberry	*Fragaria spp.*	Rosaceae	-	-
Dogwood		Western flowering dogwood	*Cornus nuttallii* Audubon ex Torr. A. Gray and/or *C. stolonifera* Michx.	Cornaceae	-	-
Yellow cedar		Yellow cedar, Alaska cedar	*Callitropsis nootkatensis* (D. Don) Oerst. Ex D.P. Little	Cupressaceae	-	-

6.1.2 Gathering areas

Many traditional gathering areas were mentioned in the OSU and CWU interviews. These are given in Table 4. The exact locations of gathering areas are matters of cultural sensitivity and as per our MOU with the Port Gamble S'Klallam Tribe are omitted from this report to the USGS.

Table 4. Port Gamble S'Klallam gathering sites. Specific locations have been omitted from this USGS report, in accordance with the requirements of the MOU.

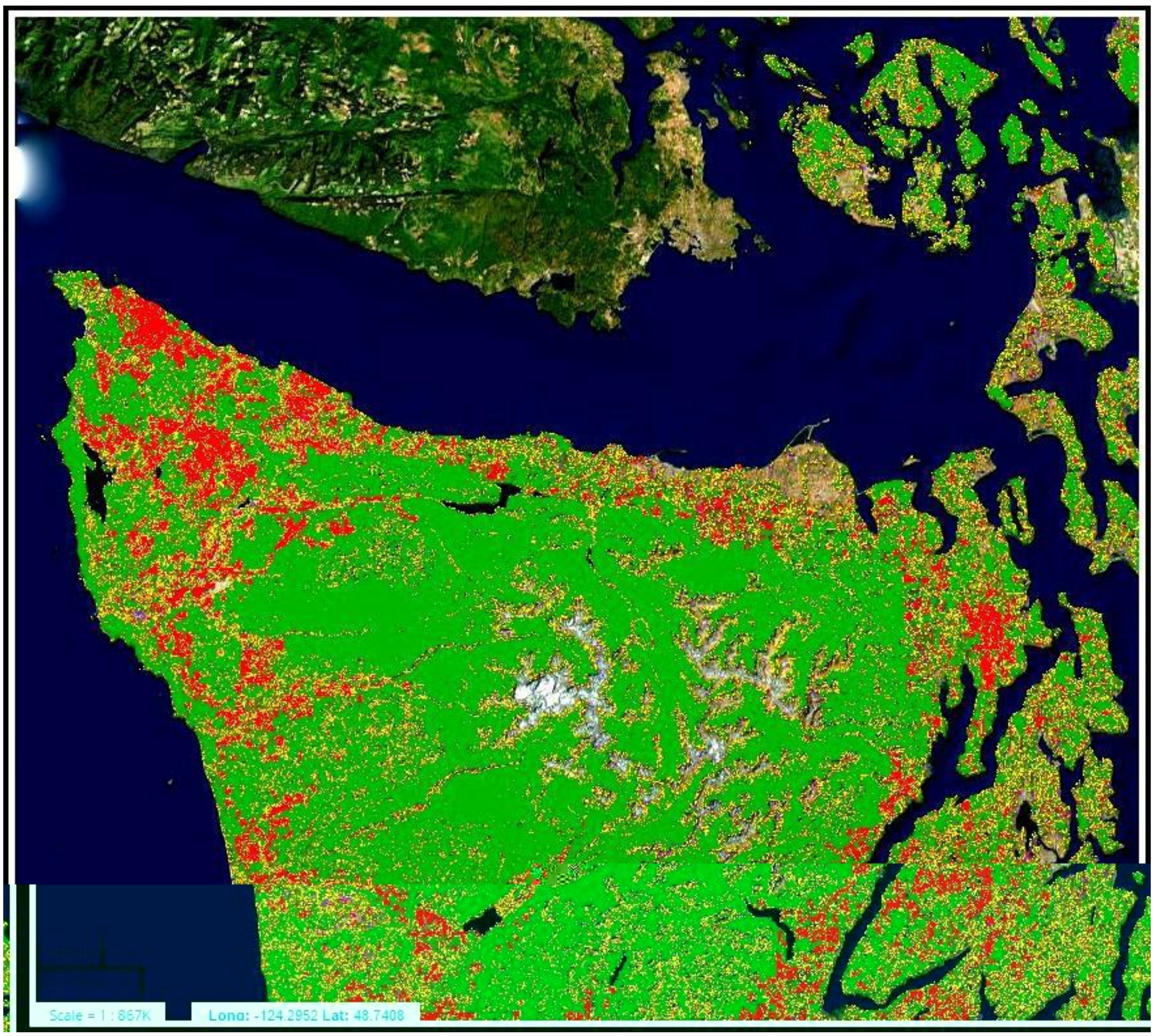
Gathering Area	Details
Bars	Seaweed, yew wood, blackberries, raspberries (blackcaps), wild strawberries, yarrow (squirrel tail)
Coon Town	Blackberries, and black and red huckleberries
Discovery Bay	Suxqum berries (soapberries) at Oil Peninsula Rd.
Drunk's Hill	Port Gamble Road: Ocean spray (ironwood) and prince's pine (no longer there)
Foulweather Bluff – Hawk's Hole	Berries
Grocery store	See Mt. Jupiter
Hansville/Skunk Bay	Berries and kelp
Hazel Point	Red and black huckleberries
Jakes Creek	Blackberries, dogwood, cedar
Martha John Creek	Cedar and blackberries
Middle Creek	On Little Boston Road. Gathered berries near shore, and cedar bark.
Mt. Jupiter	Approximate area; ocean spray (ironwood), prince's pine, and yarrow. Believed to be ~ five gathering sites in this vicinity.
Penny Creek	Near Quilcene: red and black huckleberries, blackberries, and devil's club
Port Ludlow Head	Blackberries, camas (potatoes), wild onions, suxqum berries (soapberries)
Port Townsend 1	Suxqum berries (soapberries). Prince's pine.
Port Townsend 2	Ocean spray (ironwood)
Port Townsend 3	Suxqum berries (soapberries)
Pt. Julia	Kelp and yarrow (squirrel tail)
Quilcene 1	Prince's pine
Quilcene 2	Burned brush for better plant harvest
Sequim Bay	Woods Rd. by Sequim Bay: yew wood and cedar bark
Shine	Berries
Teal Lake	Blackberries and black huckleberries
Thorndyke Rd.	Black and red huckleberries
Twin Spits	Wild onion, nettles, native carrots, potatoes (camas), yarrow (squirrel tail)
Whiskey Spit	aka Indian Island. Gathered salal, huckleberries, and kelp. Note that PGST citizens are unable to freely access this traditional gathering site, as it has been converted to a US military installation. Access can only be gained infrequently, through a formal permitting process.

Many of the traditional harvesting areas in Table 4 have been appropriated for other uses by private and public landowners in the Usual and Accustomed gathering areas. Many have been logged. Some now support primarily grass and non-native vegetation; some are covered with buildings and asphalt. Some (notably Whiskey Spit) can only be entered occasionally, and require a formal permitting process to access. Most have no protection, and their availability as a source of culturally important plants and habitats is at best tenuous.

6.2 Conventional scientific approaches

forested area. Jefferson County has suffered the least change with a 2.24% decrease in core forested area and a 3.44% increase in non-core forested area. Core Forest Areas are forest pixels that are relatively far from the forest/non-forest boundary. Essentially these are forested areas surrounded by more forested areas. This is significant when researching plants of key cultural significance which are more likely to be found within the core forest because of its tendency to sustain greater biodiversity (Lone Fight 2014).

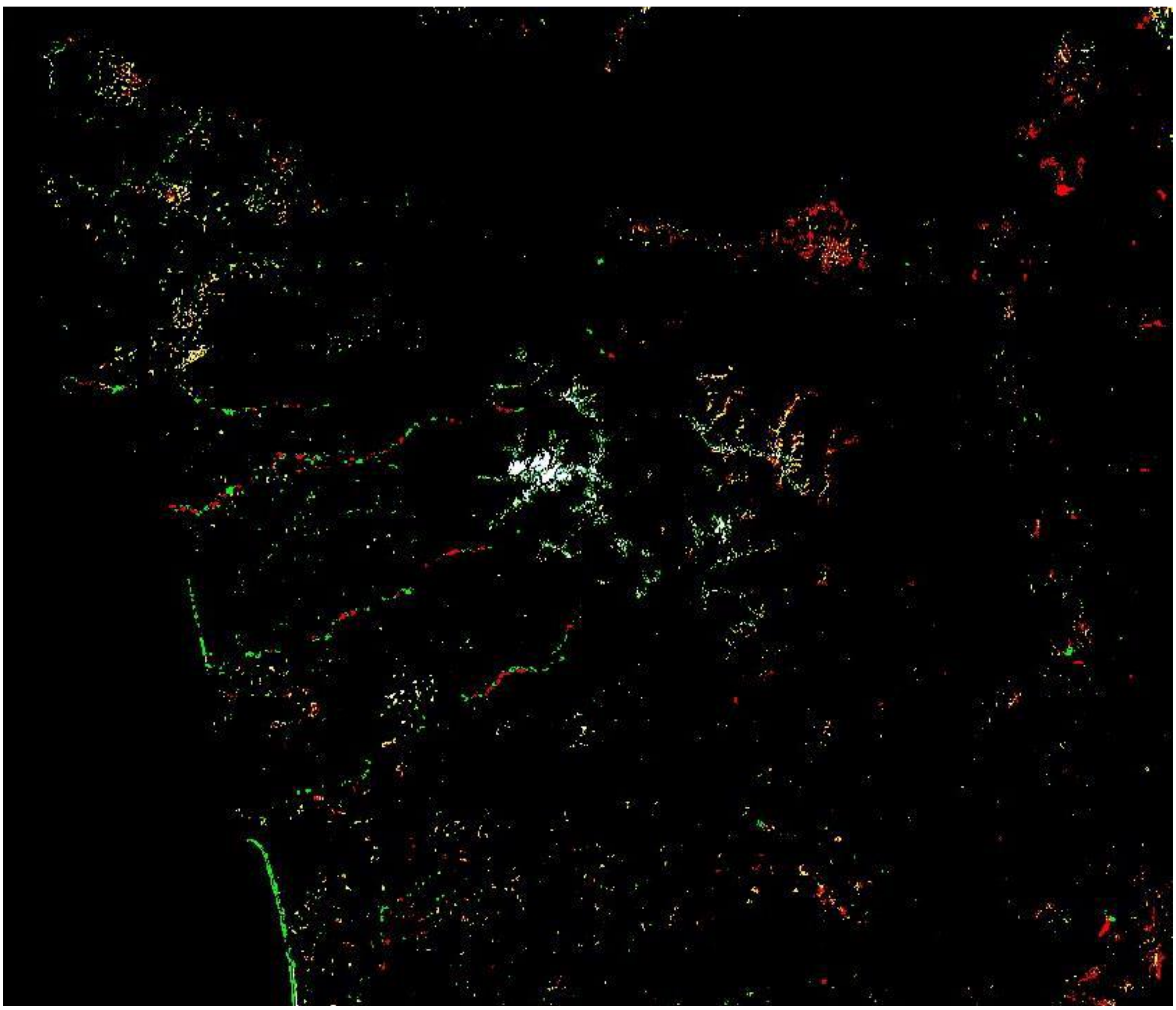
Figure 3. Distribution of Forest Fragmentation by type (1990 to 2010) for Jefferson, Clallam and Kitsap Counties. Red represents change.



6.2.1.2 Land change in wetland areas

We see similar issues with the freshwater (palustrine) wetlands areas. In Kitsap County, 4.8% of the Kitsap County area was wetland in 1996 and 4.79% was wetland in 2010 yielding a 0.12% net decrease in total wetlands (Figure 4). Clallam County saw a .71% decrease in freshwater wetlands and a 1.16% increase in saltwater wetlands for a net increase of 1.16%. Jefferson County saw a 1.86% decrease in freshwater wetlands and 8.25% increase in saltwater wetlands. There also has been a disturbing loss of 3.16% of saltwater (estuarine) wetlands. Saltwater wetlands are the home of significant numbers of traditional women's plant species (Lone Fight 2014).

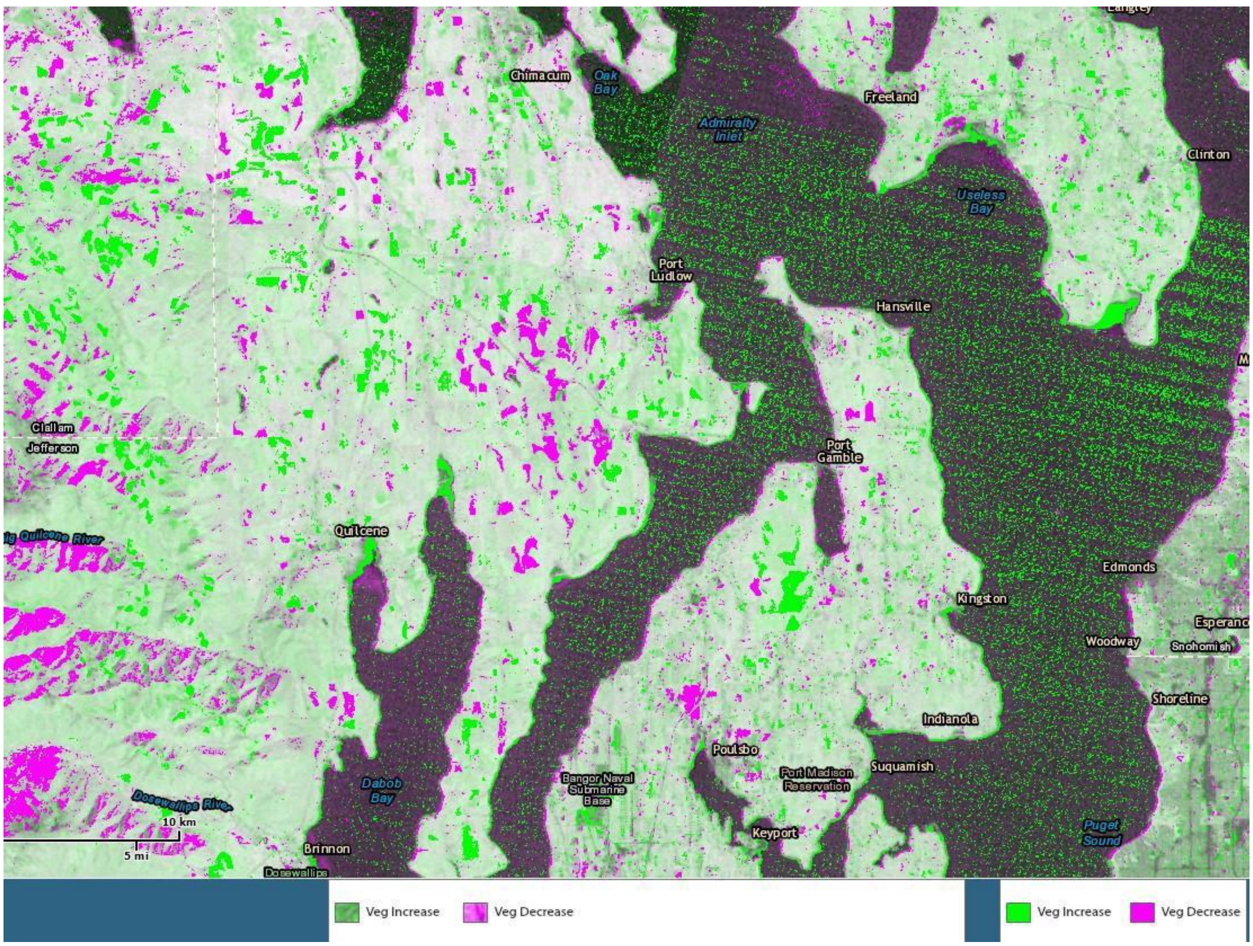
Figure 4. Change in Wetlands from 1990 to 2010 in the Usual and Accustomed Areas. Red represents decrease in areal extent.



6.2.1.3 Bidirectional change

While change is occurring rapidly in the Usual and Accustomed Area, measurements of percent change can be misleading. Change is bidirectional. Certain areas are increasing in vegetation and others are decreasing, thereby offsetting one another. The scope of change can be seen where both increased and decreased vegetation are highlighted. In Figure 5 we can see significant changes in both directions within a 20 year span from 1990 to 2010. This is important because while many species rely on stability others flourish in a disrupted environment, particularly invasive species (Lone Fight 2014).

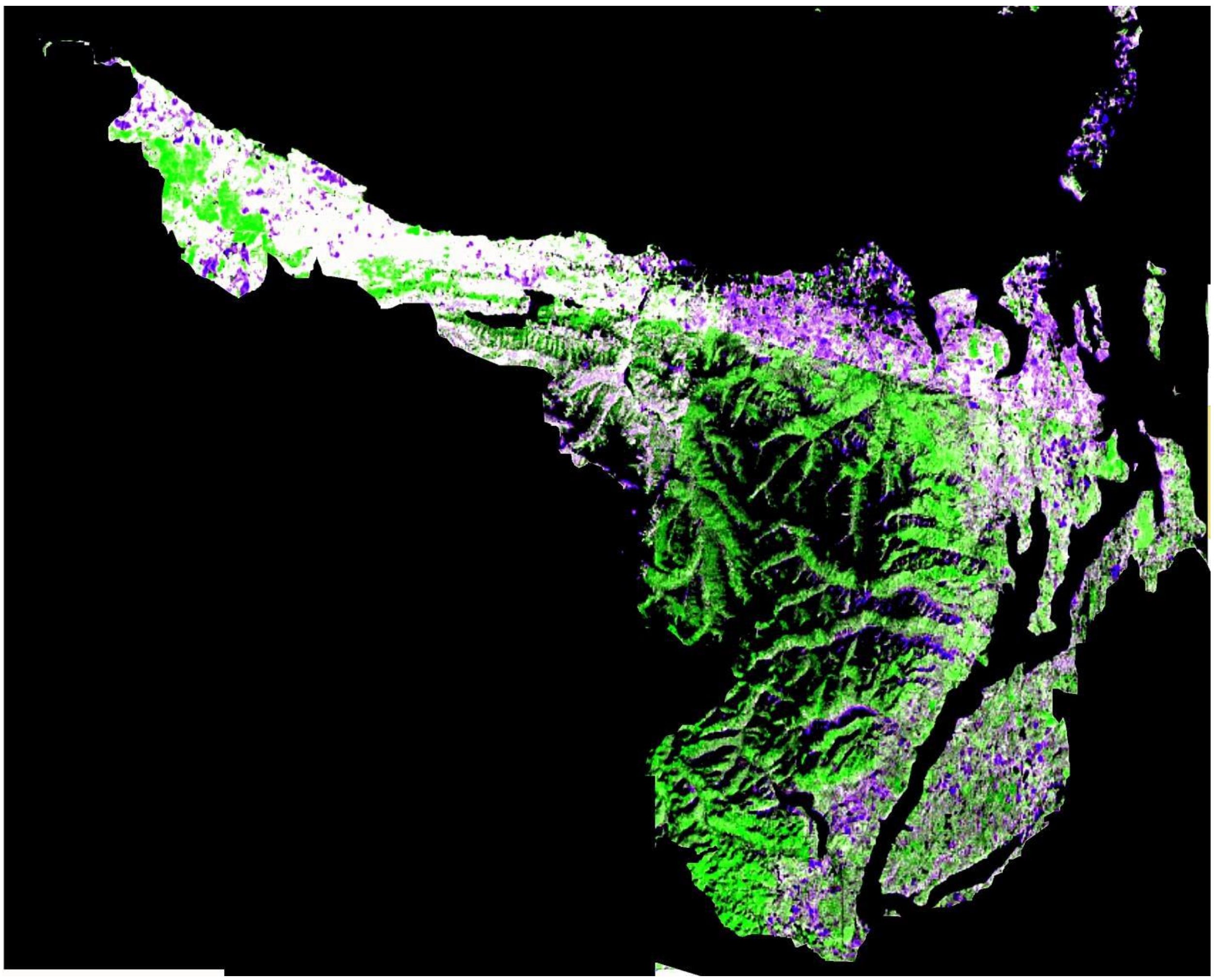
Figure 5. Land Cover Change from 1990 to 2010 in the Kitsap Peninsula Area.



6.2.1.4 Point No Point Usual and Accustomed Area

Substantial land use cover change has occurred in the Point No Point Treaty Usual and Accustomed Areas as demonstrated in the following image displaying bidirectional change from 1975 to 2010 (Figure 6) (Lone Fight 2014).

Figure 6. Land change in the Point No Point Usual and Accustomed Area 1975 – 2010. Image is a false color infrared because Landsat only collected infrared data in 1975. Image is contrast stretched to highlight change. Magenta represents decreased vegetation, green represents increased vegetation.



6.2.2 Focal plant species

Many culturally important plants were mentioned during interviews and field work with elders and the PGST Cultural Coach. In considering the following sections, we remind the reader again that indigenous taxonomies do not map in a one-to-one fashion onto Linnaean classifications. As taxonomies are provisional, the inferred results with respect to particular species should also be held as provisional.

6.2.2.1 Current distribution

The PLANTS database (USDA, NRCS 2015) considers all but one of the focal species (yarrow/squirrel tail) native to our region; yarrow is considered native to Alaska and Greenland, but is considered both native and introduced in Canada and the lower 48 states of the USA. Herbarium records confirm the presence of yarrow in our region as early as the late 19th century. Indigenous observations might be helpful in establishing a longer timeline of observations. An obvious mechanism for dispersal south from Alaska is indigenous trade networks.

According to PLANTS, only Mason County reports contemporary presence of all eight species. All but two of the focal species (prince's pine and yarrow) have gaps in distribution in the four county area encompassing the Point No Point Usual and Accustomed Area (Figure 7).

Cascara/buckthorn, devil's club, and cattail may not currently occur in Jefferson County. No specimens of cascara or devil's club have ever been deposited from Jefferson County into any of the 33 herbaria participating in the Consortium of Pacific Northwest herbaria (Table 5); only one specimen of cattail from Jefferson County has been deposited, although that was a collection made in 1928 (Table 5). Cattail is also not currently reported from Clallam County, although one specimen collected in 1975 has been deposited (Table 5).

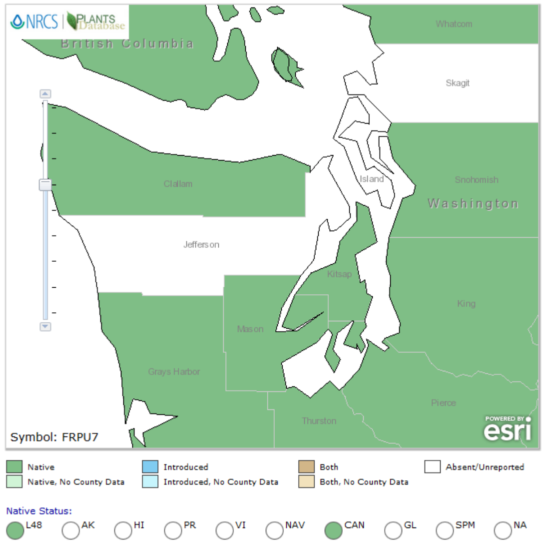
The PLANTS database suggests that soapberry/sxasum, devil's club, western redcedar, and yew may not currently occur in Kitsap County (Figure 7). However, all but soapberry/sxasum have had at least one specimen deposited (Table 5). Devil's club has had only one specimen deposited (1959). However, yew has had three (1975-2004), as has western redcedar (1975-2003) (Table 5).

Data aggregated to the county level can be misleading, as even a single record will trigger reported presence throughout the whole county. The important message to be gleaned is that two different approaches (elders' observations and botanical records) give reasonably consistent results regarding plant distribution. This suggests that the spotty records of botanical collection are probably not an artifact of under-reporting by Western scientists.

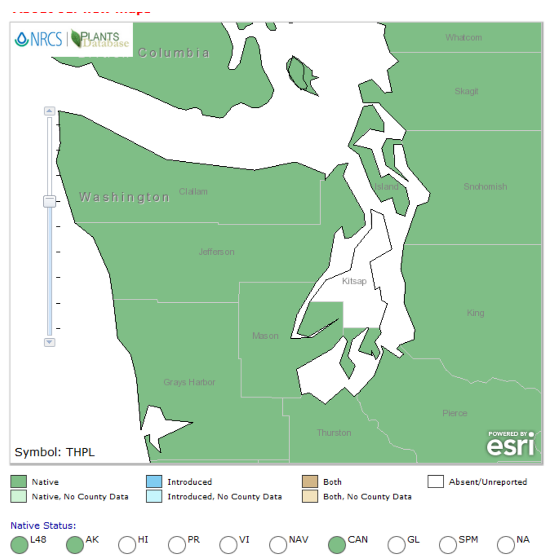
The interruption in the distribution of western redcedar in the Kitsap county portion of the U&A (Fig. 7) is puzzling. It is unlikely to be due to either climate or edaphic factors, as this species has a relatively wide ecological amplitude (Lesher and Henderson, 2010) and Kitsap County is not marginal with respect to its geographic range or environmental requirements. Yew (*Taxus brevifolia*), another fire-sensitive, late-successional focal species that is known to recover only slowly from major disturbance (Busing et al. 1995), has the same distribution gap in Kitsap County (Figure 7). Indeed, the earliest herbarium specimens of both western redcedar and yew in Kitsap County date back only to 1975.

Figure 7. Current distribution of eight focal species of particular concern to PGST elders. Data source: USDA, NRCS 2015.

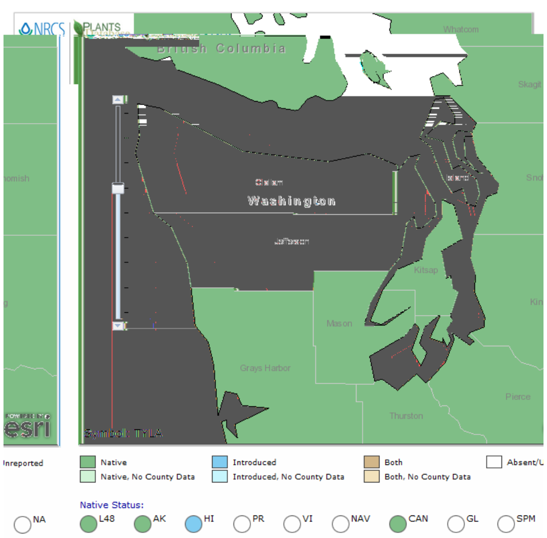
Buckthorn/Cascara (*Frangula purshiana*)



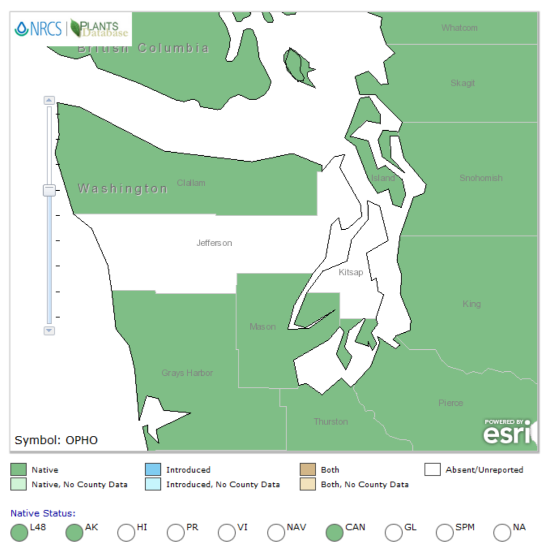
Western redcedar (*Thuja plicata*)



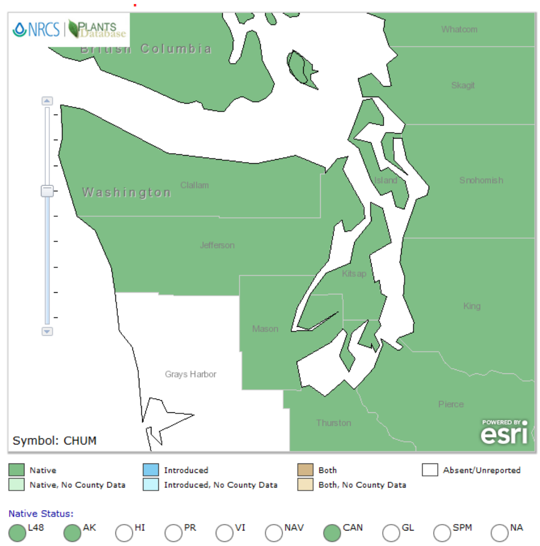
Cattail (*Typha latifolia*)



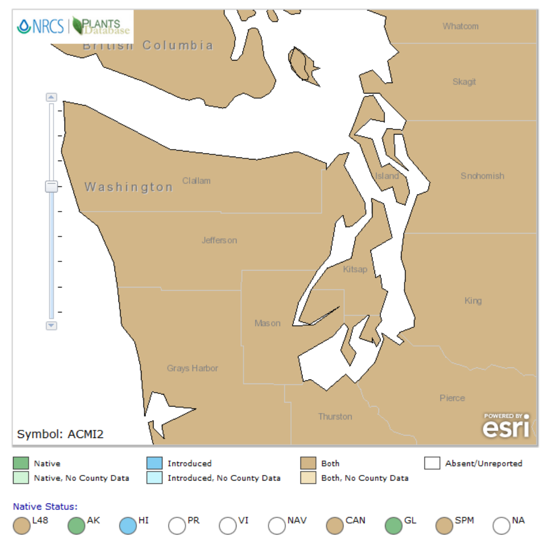
Devil's Club (*Oplopanax horridus*)



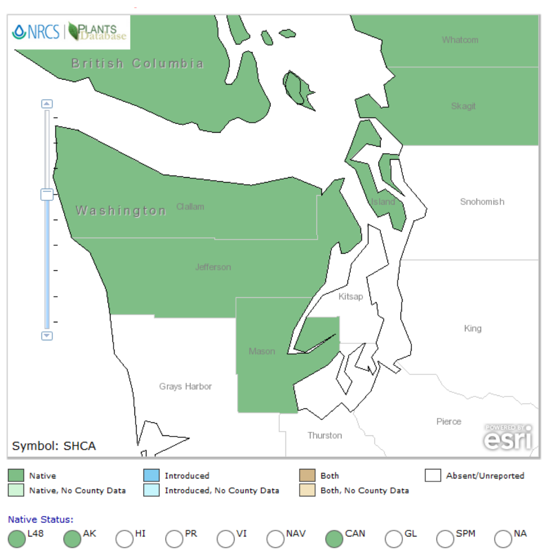
Prince's Pine (*Chimaphila umbellata*)



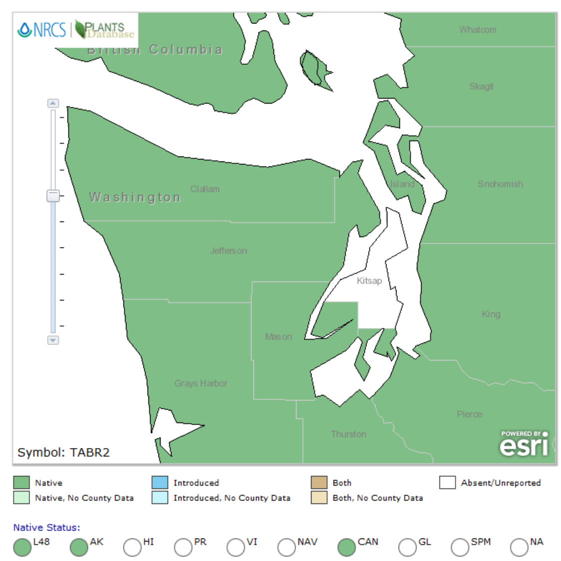
Yarrow (*Achillea millefolium*)



Soapberry/Sxusem (*Shepherdia canadensis*)



Yew (*Taxus brevifolia*)



As it turns out, intensive logging had already felled much of the merchantable timber of Kitsap County by the turn of the 19th/20th centuries:

> *"[Kitsap County] was originally entirely covered with heavy [Douglas-] fir forests. These have been removed almost completely by the ax from the shores and the islands bordering them. Only a trifling area in the southern portion of the county has been burned, while nearly half the area has been logged. The standing timber consists entirely of [Douglas-] fir."*
>
> *Gannett 1902*

Data given in a table on p. 10 of Gannett (1902) indicate that only 6.3, 7.6, and 21.4% of the timbered landscape had been cut in Jefferson, Clallam, and Mason counties (respectively) at the turn of the 19th/20th century, whereas in Kitsap County 45.5% of the timbered landscape had already been cut. Numerical estimates were given for total remaining standing timber, including "red fir" (=Douglas-fir) (Hermann and Lavendar 1990), spruce, cedar, hemlock, "lovely fir" (*Abies amabilis*), and other species. Three of the four counties covered by the U&A had estimated volumes of 10^5-10^6 million board feet in each of these species; in Kitsap County, however, the entire remaining estimated volume was in Douglas-fir (Gannett 1902).

Table 5. Collections of focal species deposited to any of the 33 herbaria of the Consortium of Pacific Northwest Herbaria for Washington counties of interest. Cla = Clallam County, Jeff = Jefferson County, Mas = Mason County, Kits = Kitsap County. Dates are the first and last dates of deposit of specimens.

Common name	Species	Cla #	Cla dates	Jeff #	Jeff dates	Mas #	Mas dates	Kits #	Kits dates
Cascara/ buckthorn	*Frangula purshiana*	9	1900-1996	**0**		5	1910-1972	4	1926-1976
cattail	*Typha latifolia*	1	1975	1	1928	2	1925-1925	2	1889-1976
Devil's club	*Oplopanax horridus*	8	1900-2000	**0**		2	1950-1950	1	1959
Prince's pine	*Chimaphila umbellata*	20	1900-2000	9	1931-2010	5	1950-1967	4	1907-1967
Soapberry /sxusem	*Shepherdia canadensis*	2	1933-1933	6	1921-1995	1	1940	**0**	
Western redcedar	*Thuja plicata*	10	1900-2000	6	1890-2011	6	1910-1975	3	1975-2003
yarrow	*Achillea millefolium*	24	1896-1995	8	1902-2006	4	1892-1949	4	1928-1976
yew	*Taxus brevifolia*	7	1900-1977	1	1975	7	1899-2012	3	1975-2004

Based on available data from the literature, the extent to which western redcedar may have historically occupied habitats of Kitsap County is not known. Western redcedar is known to require mineral soil to reproduce (Minore 1990); perhaps the dense old growth Douglas-fir forests of Kitsap County so rapidly devastated by early loggers were inhospitable for germination of western redcedar. Deeper insight into this apparent paradox could probably be gained by conversation with PGST elders.

6.2.2.2 Catalogue of climate-related ecological data

Ecological information for focal species on climate-related parameters (temperature, precipitation, moisture, hydrology) is sparse (Table 6). Specific search strategies and the complete list of references for each taxon are given as Appendix 2. Because of the paucity of climate information, we elect to discuss only three species: western redcedar (*Thuja plicata*, an old growth species that has sustained high levels of commercial harvest, but for which there is a relatively robust literature), cattail (*Typha latifolia*, an obligate wetland species), and yarrow (*Achillea millefolium*, a species considered introduced to Canada and the contiguous USA (Figure 7)). Readers interested in the few studies on other focal species are referred to Appendix 2.

Western redcedar (*Thuja plicata*): *Thuja plicata* is native to lowland coniferous forests of northwestern North America (USDA, NRCS, 2015). It is a component of the *Tsuga heterophylla* zone (Franklin and Dyrness 1973), within which it is considered a mid-successional element (Franklin and Hemstrom 1981). It is long-lived, fire-sensitive, and moderately shade tolerant, and although it is thought to reproduce poorly in old-growth stands it appears to maintain a stable gap-related age class distribution despite poor reproduction at any given time (Franklin and Hemstrom 1981). Within Washington, western redcedar is largely confined to Level III ecoregions 1-4 and 77 (Coast Range, Puget Lowlands, and lowland forests of the Cascades and North Cascades), generally regions of mild winters and high precipitation. Data regarding empirical relationships of *T. plicata* with respect to eight climatic parameters related to temperature and precipitation can be found in Thompson et al. (2012).

Temperature and precipitation affects different life stages of western redcedar (seedlings, saplings, mature trees) in different ways, and also affects factors such as propagule dispersal, seed set, and germination (e.g., Zobel et al. 1976, Lesher and Henderson 2010). However, experimental data are few and are not a useful way to determine relationships between climatic factors and forest species, because the life span of lowland PNW conifer forests is measured on time scales on the order of centuries to millennia.

Ettinger et al (2011) analyzed increment cores of six Pacific Northwest conifers in each of seven altitudinal zones of Mt. Rainier as they relate to nine potentially explanatory climate variables documented over almost a century within their altitudinal transect. They fit 32 linear mixed-effects models for each species at each elevation. While climatic factors seem to determine upper altitudinal range limits of three higher-elevation species, *Thuja plicata* (as well as two other lowland (<1200 m) conifer species) showed poorly synchronized annual growth among individuals, suggesting that local biotic processes such as competition, rather than stand-level effects such as climate, were the primary influences on growth, although at the lowest elevation (704 m), a significant negative relationship was found with snow duration. On the other hand, higher elevation populations demonstrated statistically significant (positive) relationships with growing degree days, as well as with total growing-season precipitation. Dendrochronological studies by other authors in the eastside forests of the Olympic Mountains (Dungeness watershed) agree that growth of lowland coniferous forest species, including western redcedar, seems to be limited by summer moisture deficits due to both decreased precipitation and increased temperature (Nakawatase and Peterson 2006).

Table 6. Summary of climate-related literature for eight focal species.

Common name	Species	Wetland status[1]	# of papers with climate-related information	Other literature (not consulted)
Buckthorn/cascara	*Frangula purshiana, Rhamnus purshiana*	FAC	0	Medical/pharmaceutical, horticultural
Cattail	*Typha latifolia*	OBL	5	Contaminant, wastewater treatment, toxin/heavy metal removal
Devil's club	*Oplopanax horridus*	FAC	4	Medical/pharmaceutical
Prince's pine	*Chimaphila umbellata*	UPL	1	Medical/pharmaceutical
Soapberry/ sxusem	*Shepherdia canadensis*	UPL	2	Herbal/medicinal uses
Western redcedar	*Thuja plicata*	FAC	17	(none)
Yarrrow	*Achillea millefolium*	FACU	4	Medical/pharmaceutical
Yew	*Taxus brevifolia*	FACU	2	Medical/pharmaceutical

[1] Source: USDA, NRCS 2015; Key to Wetland Status codes: FAC (Facultative)-Occurs in wetlands and non-wetlands; FACU (Facultative Upland)-Usually occurs in non-wetlands, but may occur in wetlands; FACW (Facultative Wetland)-Usually occurs in wetlands, but may occur in non-wetlands; N/A: Not applicable; OBL (Obligate wetland)-Almost always occurs in wetlands; UNK: Status unknown; UPL (Obligate Upland)-Almost never occurs in wetlands.

Cattail (*T. latifolia*): Cattails are perennial wetland obligates generally considered to be weedy, invasive species (e.g., Yeo 1964, Xu et al. 2013). They were once considered a good candidate for biofuels (Pratt and Andrews 1980), and recently have come under renewed attention for this use (e.g., Zhang et al. 2012). Early research focused on the plasticity of various species of cattail, including *T. latifolia*, for which many ecotypes appear to exist (e.g., McNaughton 1966, 1973). *T. latifolia* is native to North America, and distributed throughout Alaska, Canada, and the lower 48. The few potentially climate-related studies that our search strategy uncovered (Table 6, Appendix 2) discuss responses to temperature and to drought/flooding regimes.

In Canadian Prairie ecosystems, springtime flooding of open *Eleocharis palustris* (spikerush) wetland communities has been pursued for decades in order to increase populations of breeding waterfowl. This has resulted in an increase of invasive *Typha latifolia*. Asamoah and Bork (2010) used controlled greenhouse experiments to determine whether specific drying regimes would be successful in controlling cattails, which they see as a part of a successional replacement regime. Under low moisture conditions this obligate wetland species had reduced growth and survival, although it was considerably more drought-tolerant than the *E. palustris* it was outcompeting it in the field. Complete root mortality of *T. latifolia* was only achieved with soil moistures <5%, whereas *E. palustris* was susceptible to even short-term soil drying.

T. latifolia can also survive moderate flooding. Mesocosm experiments in Louisiana demonstrated, however, that in deeper water it has a lower shoot density and decreased incidence of flowering (Grace 1989). In those experiments, *T. latifolia* died out at depths > 95 cm.

Greenhouse experiments by Li et al. (2004) confirm that although *T. latifolia* thrives under modest flooding, it can be susceptible to periodic droughts that decrease both net photosynthetic rates and stomatal conductance.

Finally, Jones et al. (1979) propose that populations of *T. latifolia* from different regions of North America have evolved different means of adapting to temperature.

As a phenotypically plastic, widely distributed weedy wetland species particularly tolerant to droughty conditions, the decreasing presence and/or abundance of *T. latifolia* from traditional gathering places in the Point No Point U&A is striking. Because we found no specimens, we are not even sure whether the taxon in question really is *T. latifolia*, which is important because Typha species, including T*. latifolia* hybrids, differ in ecologically significant ways (e.g., Smith 1986). This point becomes particularly important if/as restoration projects are anticipated.

Yarrow (*Achillea millefolium*): Yarrow is another perennial species whose documented paucity by PGST elders is puzzling. It is arguably one of the best known and most widely distributed species in the northern hemisphere (e.g., Beaubien and Hamann 2011). It is particularly common in disturbed habitats (e.g., Wein et al. 1992), although it is also shade-tolerant (Warwick and Black 1982). Genetically, it is a complex polyploid group, with both tetraploid and hexaploid races (Warwick and Black 1982). It is considered invasive throughout most of North America from original centers of distribution in Alaska and Greenland (USDA, NRCS 2015). Yarrow has a wide climatic range, is quite tolerant to drought, grows over a great diversity of soil types (including very poor soils), and spreads rapidly by vegetative means, which is probably why it can so easily invade closed meadow, pasture, and lawn communities (Warwick and Black 1982).

On the other hand, allocation to seed production is low, and sexual reproduction in this self-incompatible species is dependent on insect pollination (Warwick and Black 1982). In Alberta, Beaubien and Hamann (2011) summarize the results of three observational phenology databases that collectively span 70 years (1936-2006). The substantial warming trend documented for that interval from weather stations was most pronounced for late winter and early spring, resulting in earlier springtime bloom of eight species, of which yarrow was the latest in the phenological sequence. Effects were most pronounced on the earliest-blooming species, but even yarrow is now blooming 0-6 days earlier than it did in this region in the 1930s. Bloom period is short (Beaubien and Hamann 2011), so disconnects with available insect pollinators may become problematic.

6.2.2.3 Field studies

Traditional gathering sites identified by elders to which we were permitted access were visited to assess current condition, with particular attention to the eight focal species. As expected, focal species were painfully sparse relative to historical times in which all needed species were easily found and gathered. Four focal species were not found at all (buckthorn/cascara, cattail, yarrow, and yew). In the case of yarrow, sampling in late fall and winter probably hindered detection, although all other species should have been easily found if/as they were present in areas investigated.

Seven sites were chosen for semi-quantitative phytosociological studies in order to document the current situation for the four remaining focal species as well as for oceanspray/ironwood (*Holodiscus discolor*) and black huckleberry (*Vaccinium membranaceum*) (Figure 8). More detailed locations are given in Figure 9 as swaths within USGS topographic maps. Compositional data from relevés are summarized below each map.

Figure 8. Locations of sites chosen for relevés.

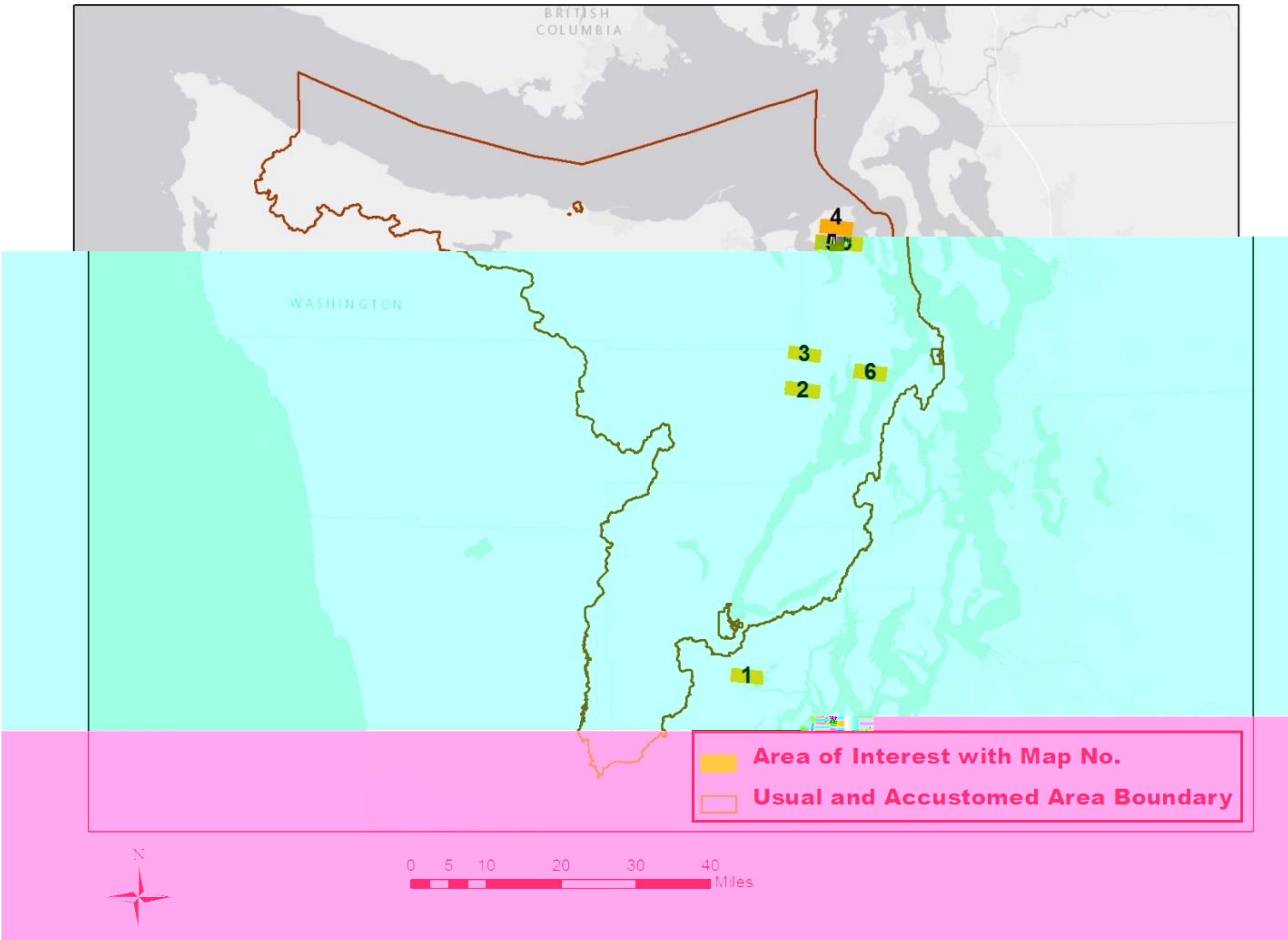
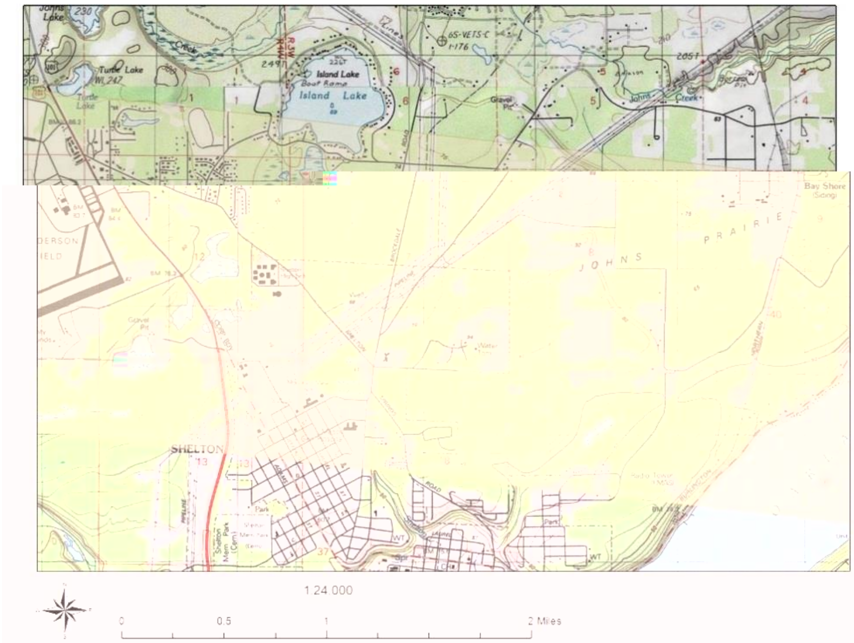
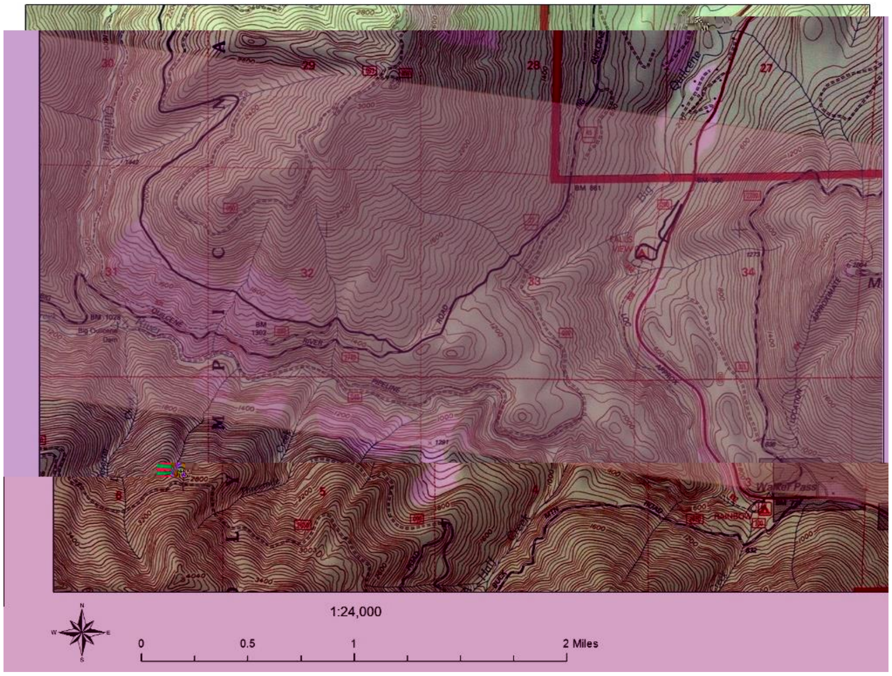


Figure 9. General locations of seven relevés for six species of interest to PGST, with general summary of phytosociological information for each relevé.



Map 1: Prince's pine

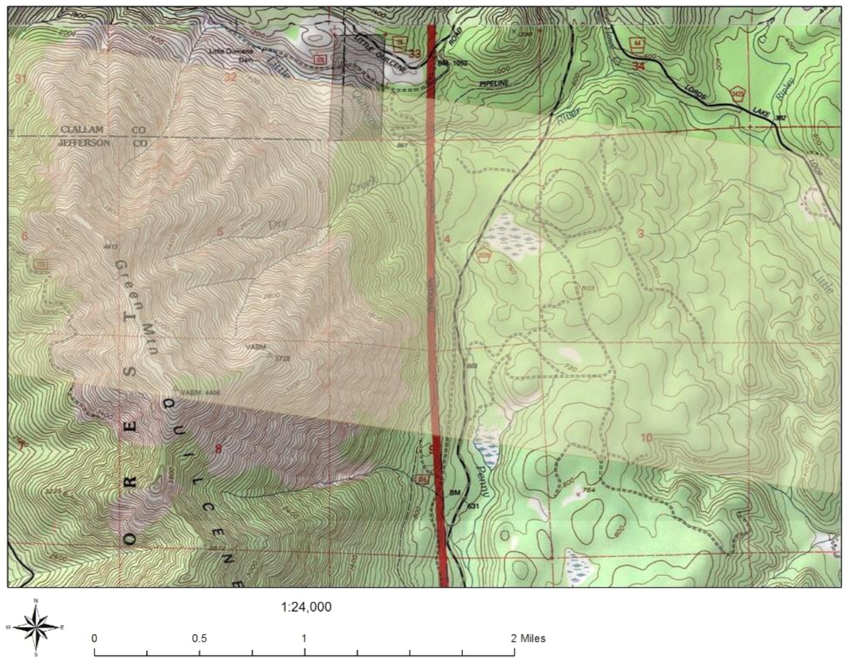
Sampled 6 January 2015
Chimaphila umbellata (prince's pine) present in understory of an almost closed Douglas-fir canopy, with Douglas-fir in the understory and a ground cover of prince's pine and moss.



Map 2: Devil's Club, Western Redcedar

Sampled 15 October and 7 November 2014

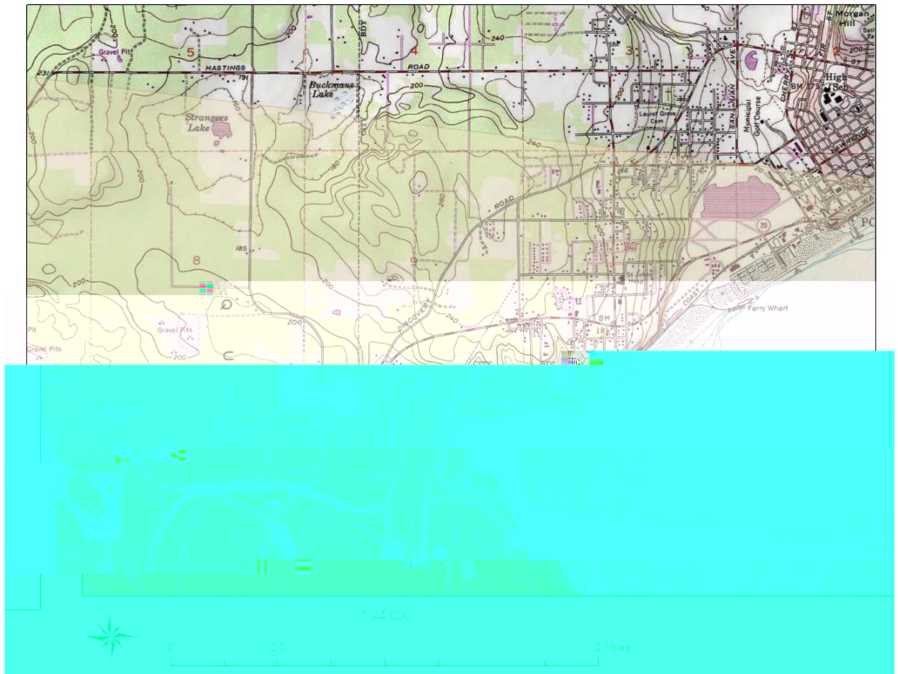
Mature *Thuja plicata (*western redcedar*)* with Douglas-fir, western hemlock, and bigleaf maple also present in overstory; all but bigleaf maple represented in subcanopy layers. Understory of ferns, mosses, and (sparsely) Devil's club, as well as the invasive *Geranium robertianum*.



Map 3: Devil's club

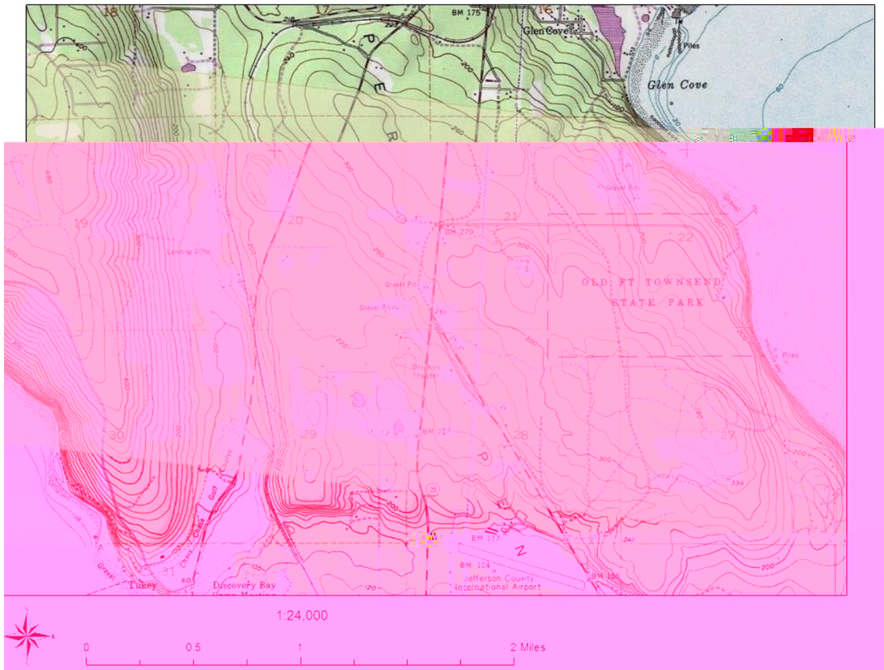
Sampled 6 November 2014

Douglas-fir/red alder stand with accompanied by western hemlock in the subcanopy, and *Oplopanax horridus* (devil's club) in all layers from the subcanopy to ground cover. Sword fern also present in high ground cover. Mosses, forbs, and maidenhair fern in low ground cover.



Map 4: Oceanspray/Ironwood

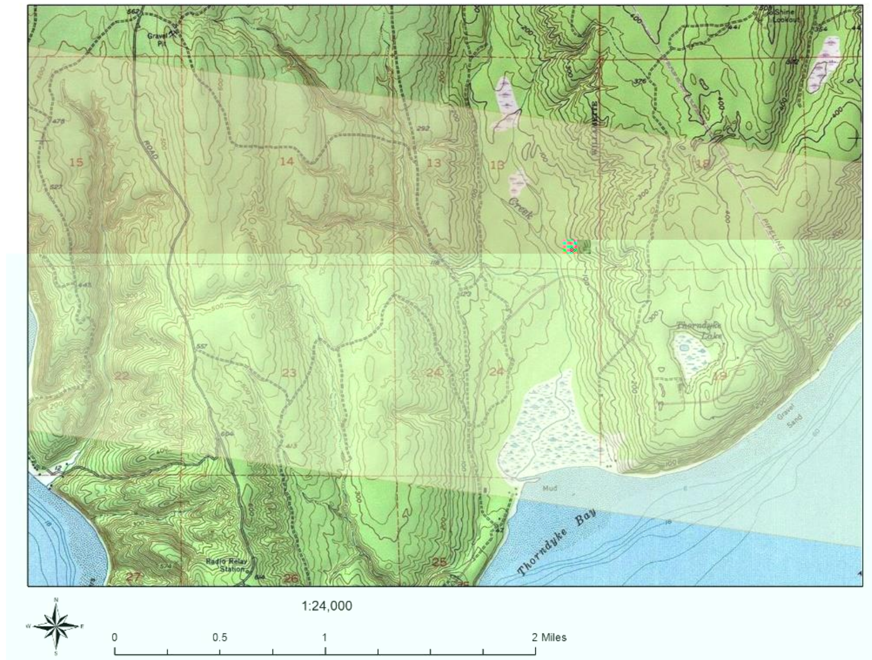
Sampled 21 November 2014
Douglas-fir stand accompanied by madrone in the subcanopy and *Holodiscus discolor* (oceanspray/ironwood), salal, and rhododendron in the low subcanopy accompanied by snowberry and huckleberry in the understory. Groundcover of ferns, forbs, and blackcap (black raspberry)



Map 5: Soapberry/Buffalo Berry

Two sampling locations in this area.

1. *Sampled 21 November 2014*: Western redcedar, Douglas-fir, madrone, and red alder in the canopy, with sparse *Sherpherdia canadensis* (soapberry/buffalo berry) in the low canopy and high understory and salal, red huckleberry, and Douglas-fir seedlings in the low understory. Ground cover composed of grasses and low Oregon grape.
2. *Sampled 19 November 2014*: Douglas-fir, madrone, and red alder in the canopy with alder and rhododendron in the subcanopy. *Sherpherdia canadensis* (soapberry/buffalo berry) in the groundcover, accompanied by rhododendron, salal, snowberry, scotch broom, low Oregon grape and ferns.



Map 6: Huckleberries

Sampled 21 November 2014
Douglas-fir stand with Douglas-fir and sparse western hemlock in the subcanopy. *Vaccinium membranaceum* (black huckleberry) and salal abundant in the understory and ground cover, with sparse groundcover of low Oregon grape and bracken fern.

6.2.3 Climate change

6.2.3.1 Temperature/Precipitation (D. Sharp)

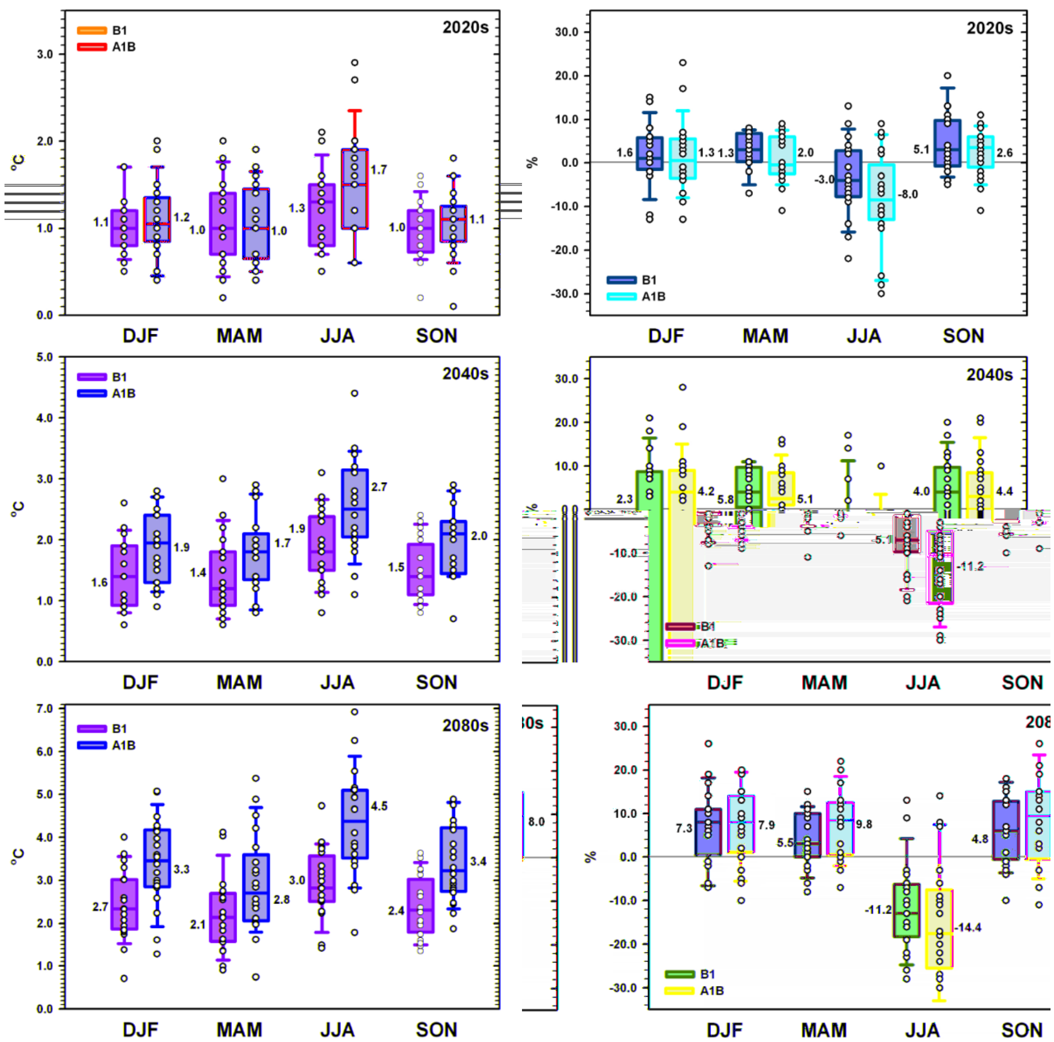
Projections of future climate can be for a range of scales, from global all the way down to sub-regional (i.e. watershed scale, for instance). Mote et al. (2011) offer guidelines on using climate model projections for impacts assessment:

1. obtain climate projections based on as many simulations, models, and emissions scenarios as possible
2. use the ensemble of models to characterize not only the projected mean, but also the range and other aspects of variability; and
3. recognize the limitations of any method(s) selected.

All of these guidelines have been applied to the following projections.

Pacific Northwest (PNW): For the PNW region as a whole (defined as 124° and 111° W and 41.5° to 49.5° N) temperature and precipitation projections by Mote and Salathé (2010), shown below in Figure 10, were based on the results of a suite of 20 Global Climate Models (GCMs). These projections were run using two widely used “marker” emissions scenarios, B1 and A1B (IPCC, 2000). Two scenarios are often chosen for studies such as this, because they can provide a “low” (B1) and a “high” (A1B) trajectory for planning purposes. It us up to the reader as to whether or not they use the low, high, or both scenarios in their assessment. The results in Figure 10 indicate warming during the 21st century, with a possible increase in the seasonality of precipitation (i.e. slightly wetter springs, falls, and winters; and slightly drier summers). Annual precipitation totals are not projected to change appreciably.

Figure 10. Range of projections for changes in PNW seasonal temperature (left) and precipitation (right) vs. the 1970-1999 mean. In each pair of box-and-whiskers, the leftmost box is for emissions scenario B1, the rightmost box is for A1B. For each box-and-whiskers plot, the whiskers indicate the10th and 90th percentiles, the box ends are the 25th and 75th percentiles, and the median of all model projections is indicated by the solid middle bar. Circles are individual model results. Printed values are the weighted Reliability Ensemble Average of all GCMs for the season and scenario (Mote and Salathé, 2010). Note: 3.0 °C = 5.4 °F.

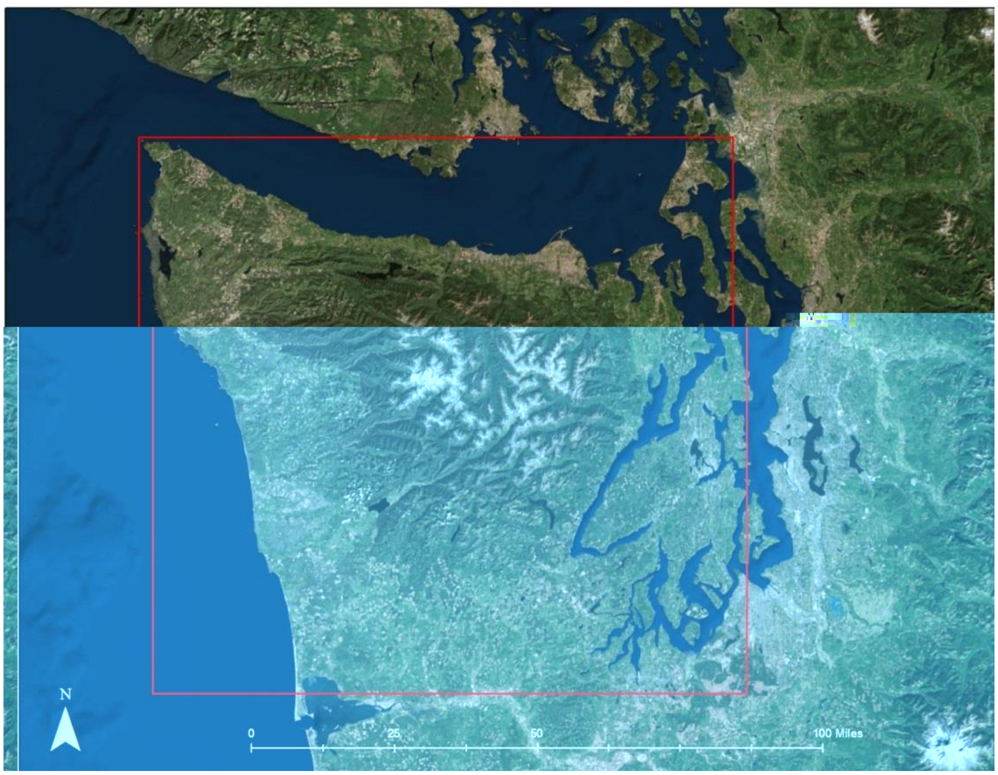


Olympic/Kitsap Peninsulas: Multi-state regional projections such as those generated by Mote and Salathé provide only limited guidance to those interested in projections on much smaller geographic scales. To this end, numerous efforts have been made to “downscale” global/regional projections to much finer resolutions. One such effort is the Multivariate Adaptive Constructed Analogs (MACA) statistical downscaling method of Abatzoglou and Brown (2011). This method downscales the model output from a suite of GCMs of the Coupled Model Inter-Comparison Project v5 (CMIP5) for the historical period (1950-2005) and the future (2006-

2100), again using two marker emissions scenarios (where RCP4.5 is the "low", and RCP8.5 is the "high" scenario) (IPCC, 2008). Note that RCP emissions scenarios are similar conceptually to SRES scenarios used in Figure 10. They both provide scientists with "forcings" (i.e. parameters) with which to drive climate models. Where they differ is in the details of how the forcings were derived. In any case, as mentioned above, two scenarios are often used in impacts assessments to provide a "high" and "low" path.

This section examines the results of MACA downscaling for the Olympic Peninsula of Washington state. The GCM outputs are downscaled from their native resolution to 6 km resolution. The exact domain for this analysis is 47.00- 48.40 N and 235.25 - 237.50 E. (Figure 11). Note that only data points over land are considered. For this analysis the results of 18 GCMs are included.

Figure 11. Domain for the MACA downscaling analysis



The following climate parameters available from MACA were analyzed:

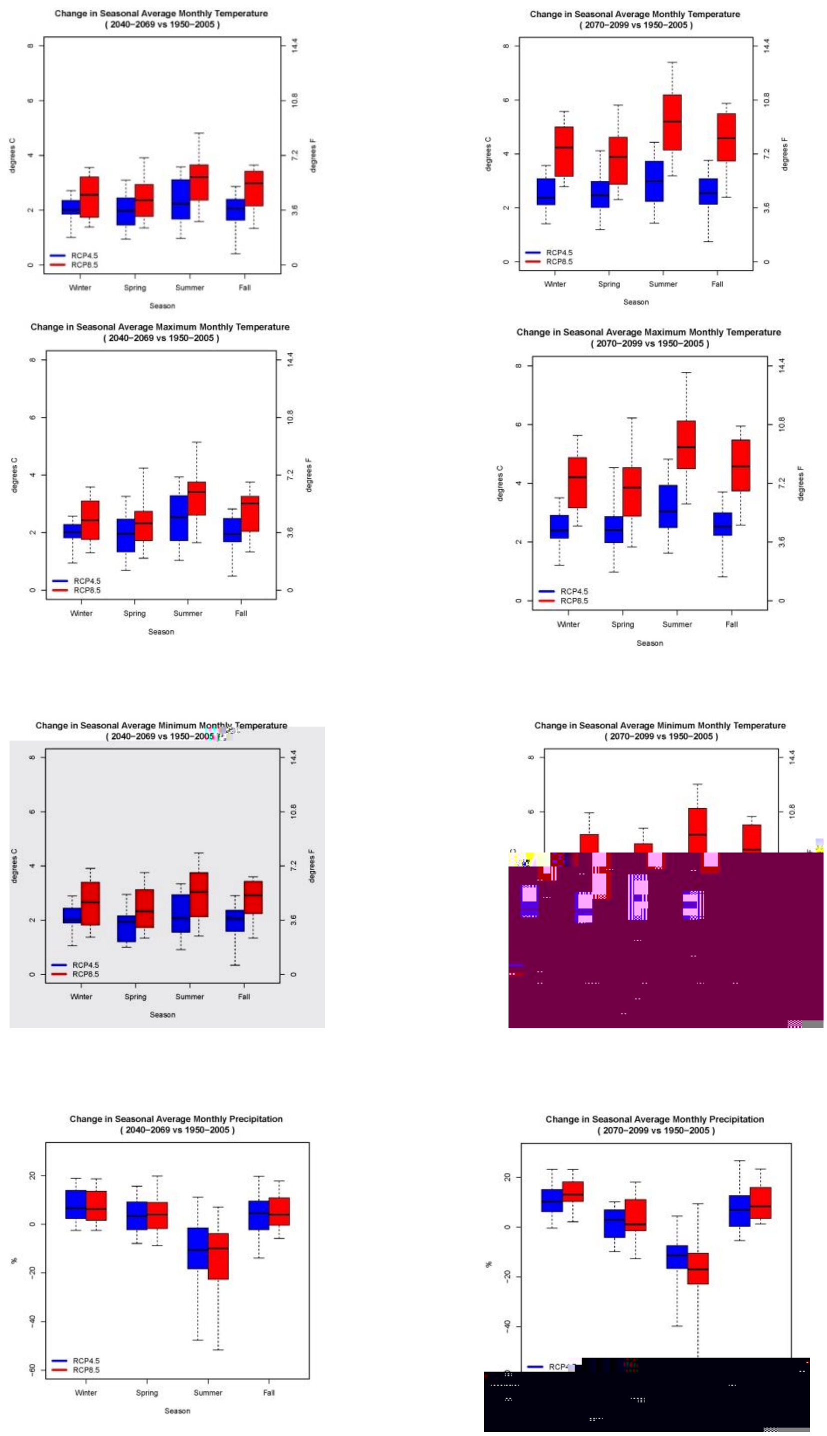
1. total monthly precipitation;
2. mean monthly maximum temperature;
3. mean monthly minimum temperature; and
4. mean monthly temperature (calculated as the average of monthly maximum and minimum temperatures).

All these parameters were aggregated seasonally, where Winter = Dec-Feb; Spring = Mar-May; Summer = Jun-Aug; Fall = Sep-Nov.

Two future time periods were examined, 2040-2069 and 2070-2099. The mean for each seasonal parameter in each future time period was compared to the historical mean (1950-2005) for that seasonal parameter. The change in temperature (future – historical) is given as the change from the historical average in degrees C (where a change > 0 projects a warmer future). The change in precipitation is also given as a change from the historical average, in this case as a percent of historical mean (a percent change > 0 projects a wetter future, and < 0 a drier one).

Figure 12 (below) illustrates the MACA derived projections for the Olympic/Kitsap Peninsula domain. These projections are broadly consistent with those of Mote and Salathé (2010): a warmer future, with increased seasonality of precipitation. The box-and-whiskers plots are similar to Figure 10, except that individual model results are not plotted, and the whiskers extend to the extreme data points (not the 10^{th} and 90^{th} percentiles).

Figure 12. Scenarios of seasonal average precipitation and seasonal, maximum, and minimum temperature for the mid and late 21st century in our region. Left column contains (top to bottom) scenarios for mean, maximum, and minimum temperature (°F), and % change in seasonal average mean precipitation, for 2040-2069 relative to 1950-2005. Right column contains the same for 2070-2099. Within each figure, blue indicates RCP 4.5 results and red indicates RCP 8.5 results. See Appendix 3 for larger versions of each of these eight figures.



Any climate modeling effort (and the resulting projections) is subject to a number of uncertainties. For regional modeling (such as discussed here for the Olympic/Kitsap Peninsula) before the mid-21st century, the uncertainty in projections arising from model uncertainty (i.e. the response of climate models) and the manifestation of climate change due to internal variability on small (i.e. regional vs. global) scales dominates. After mid-century the uncertainty surrounding emissions of greenhouse gases (and land use change) begins to grow, and dominates by 2100 (Hawkins and Sutton, 2009)

That said, notable results apparent in the plots are:

1. Consistent warming projected by all models (i.e. no model ever projects no warming), with RCP8.5 warming consistently greater than RCP4.5 warming.
2. Increased warming (compared to earlier in the century) during the late century period.
3. Considerable variability in projections for precipitation (even to the point of uncertainty about whether change will be positive or negative).

Consideration of seasonal means of temperature and precipitation is certainly an important part of any impacts analysis. However, it may also be important to consider the impacts changes to extreme climate values may have on any region (e.g. the warmest day during the summer or the heaviest single day rainfall). These extreme values may have considerable effects on plant, animal, and human communities. By necessity though, this report only looked at seasonal means.

In addition, in areas with significant topographic variation (like the Olympic/Kitsap Peninsula), averaging climate over a domain as large as the one used here will result in some loss of regional variation. It may be useful to consider smaller domains when possible. Again though, by necessity, this report only looked at the Olympic/Kitsap Peninsula as one region.

6.2.3.2 Likely changes in sea level

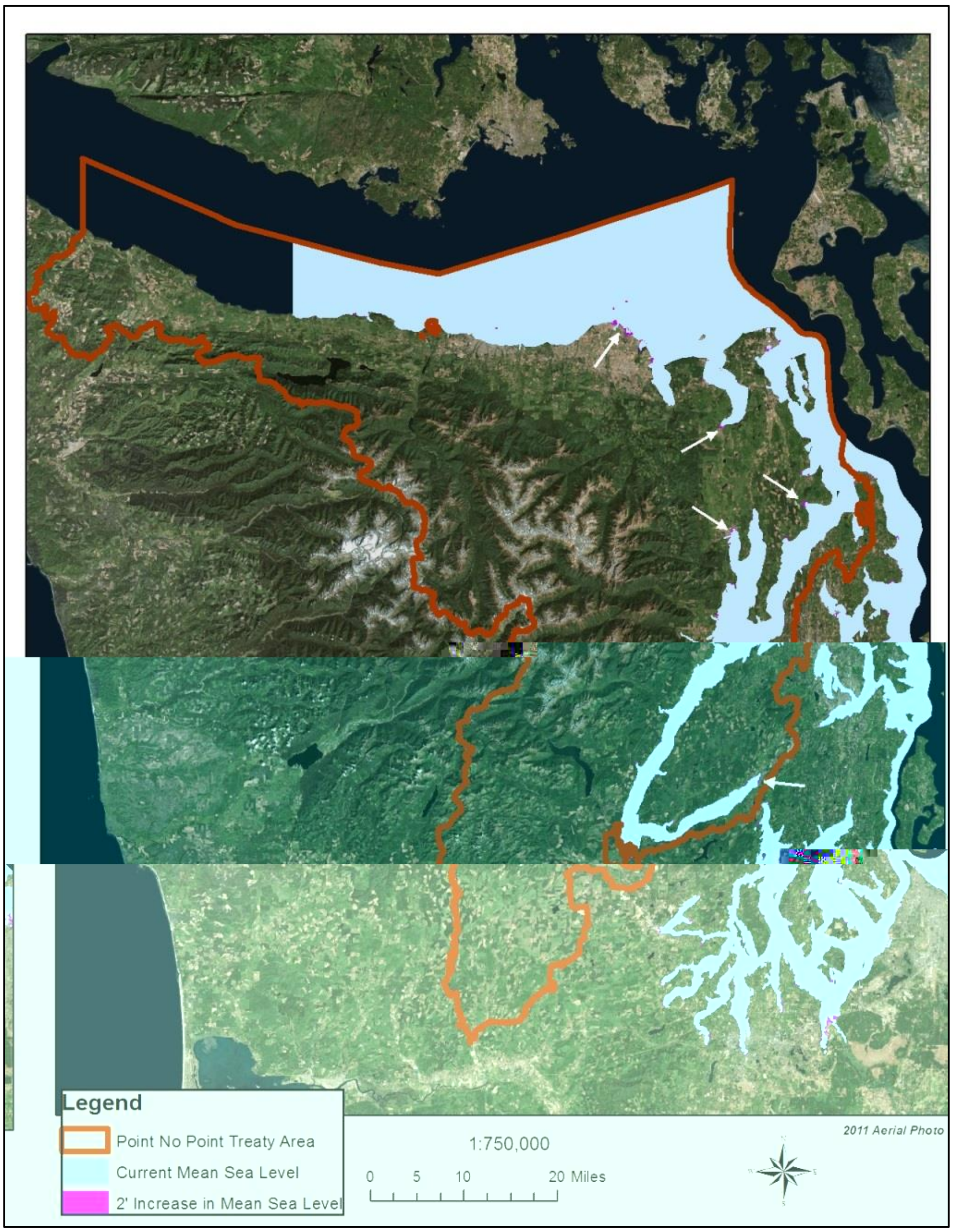
In our region, the most current projections for year 2100 sea level rise (relative to year 2000) are given in Table 7. Changing climates (melting of continental glaciers plus the thermal expansion of sea water) must be considered in the context of vertical land motion due to active subduction zone movement that can introduce significant local variability (Dalton et al. 2013).

Table 7. Estimated rise in sea level, 2100 relative to 2000. Central estimate, with full range of projections given in parentheses. Source: Dalton et al. 2013. These authors note that Mote et al. 2008's estimates include longitudinal variation in addition to the latitudinal variation considered in NRC 2012.

Region	Mote et al. 2008	NRC 2012
NW Olympic Peninsula	4 cm (-24-88)	61 cm (9-143)
Puget Sound	34 cm (16-128)	62 cm (10-143)

Figure 13 uses the NRC central estimate of 61 cm estimate (approximately two feet) as a reasonable starting place to display spatially explicit consequences for the U&A. The rise in sea level in the U&A by 2100 is expected to primarily affect the five areas indicated in the figure.

Figure 13. Current mean sea level and 2' sea level rise within U&A area. Source data: NOAA 2015. Note: data unavailable for NW corner of U&A. White arrows indicate five areas of greatest inundation.



6.2.4 Plant responses to climate change

In the western PNW (as elsewhere) there is increasing interest in how changing climates will affect forest composition and productivity. However, there are few published studies that relate any of the eight focal species directly to specific scenarios of climate change.

6.2.4.1 Western redcedar

Ettinger et al.'s (2011) dendrochronological studies of six PNW conifers across several altitudinal zones at Mt. Rainer (Section 6.2.2.2) suggest that summer warming might increase growth for higher elevation (1064-1091 m) populations of western redcedar although decreased summer precipitation may decrease growth. Moisture-related slowing in growth during summer, however, could be offset by decreased dormant season precipitation at this elevation.

Ettinger et al. (2011) conclude that climatic effects on the growth of three lowland conifer species, including western redcedar, were weaker than for three higher elevation species, and that biotic factors, primarily competition from more thermally tolerant species, are more likely to affect range contraction of western redcedar in closed canopy forests than direct climatic effects (e.g., Ettinger et al. 2011, HilleRisLambers et al. 2013). At the lowest elevations studied (704 m), a significant negative relationship with snow duration during the dormant season suggests that decreasing snow may actually enhance growth of low elevation populations of this species. It is important to note that the U&A is actually in the center of the current geographic range of western redcedar which suggests that while growth rates may slow, changes in actual distribution outside this part of its distribution are unlikely except perhaps in marginal locations associated with elevation, marine effects, etc. . In the absence of catastrophic events (e.g., wildfire), it appears that climate effects on this long-lived forest species will proceed slowly in this region.

6.2.4.2 Cattail (Typha latifolia)

The one study that relates any of our focal species to specific scenarios of climate change involves this widely distributed species of cattail. Modeling studies by Xu et al. (2013) predict that *T. latifolia* (as well as the exotic invasive *Rumex crispus* (curly dock)) may have trouble persisting under commonly referenced climate scenarios. Using the MaxEnt (maximum entropy) model (Phillips and Dudik 2008), Xu et al. (2013) predict potential distributions of each species for both current climate conditions and for 2050 conditions under several climate scenarios (IPCC-SRES, A1B, A2, A2A, and B1). Two of these (A1B and B1) are scenarios that we have chosen to discuss in this report (see Section 6.2.3.1). Compared with current condition, their modeling results indicate that both *T. latifolia* and *R. crispus* will face severe challenges in the future, due largely to warmer, wetter conditions during the coldest season. However, these counter-intuitive results are not consistent with the (admittedly sparse) experimental data from greenhouse and mesocosm studies on *T. latifolia* summarized in Section 6.2.2.

6.2.4.3 Yarrow

Allocation to seed production in yarrow is low, and sexual reproduction in this self-incompatible species is dependent on insect pollination (Warwick and Black 1982). In Alberta, Beaubien and Hamann (2011) summarize the results of three observational phenology databases that collectively span 70 years (1936-2006). The substantial warming trend documented from weather stations for that interval was most pronounced in late winter and early spring, resulting in earlier springtime bloom of eight species, of which yarrow was the latest in the phenological sequence. Effects were most pronounced on the earliest-blooming species, but even yarrow is now blooming 0-6 days earlier than it did in this region in the 1930s. Bloom period is short (Beaubien and Hamann 2011), so disconnects with available insect pollinators may become problematic.

Swedish mesocosm experiments with yarrow grown in peat suggest that increasing greenhouse gas concentrations should favor yarrow. Sæbø and Mortensen (1998) find that elevated CO_2 concentrations resulted in a 19% increase in dry weight, a result often found in fast-growing wild species (Poorter 1993).

7 ANALYSIS AND FINDINGS

7.1 Historical landscape change (L. Lone Fight)

Although pixel size does not allow for direct identification of culturally important plants via available remote-sensing technology and aerial photos are also affected by cover and canopy, significant change can be seen in the critical areas of wetlands and forests. These areas are home to a preponderance of culturally important and essential plants and therefore change in these areas can be an indication of change in the target populations.

Documentation of the changes that are taking place in the Usual and Accustomed Areas of the Point No Point Treaty does not in and of itself imply climate change as a causal source. The cause of change is confounded by multiple variables including extensive human habitation and use, reforestation efforts, protection efforts, and urban conversion among others. A more reliable barometer of such change is the observations of the indigenous people of the area whose indigenous place-based knowledge extends back thousands of years.

7.2 Climate and vegetation

In a widely cited paper, Travis (2003) suggest that climate change and habitat destruction work together to produce "a deadly anthropogenic cocktail". Research that examines the interaction of these two factors empirically is almost non-existent, so this theoretical contribution is welcome even though the models are quite simplistic. The correspondingly simple conclusion makes good common sense: habitat loss reduces the ability of a species to survive climate change. This observation is likely to be of particular concern in spatially explicit situations such as U&As (but also including state and national parks, forests, and refuges). Because habitat loss due to wholesale land conversion in U&As is likely to seriously exacerbate climate-related changes, habitat protection takes on new urgency for tribal peoples with treaty-protected rights to fish, hunt, and gather in their usual and accustomed places.

7.2.1 Western redcedar

Paleoecological studies have demonstrated that the lowland coniferous forests now characteristic of western Washington did not become established until about 6000 years before present (YBP) (

managers try to erase yarrow from cattle pasture because it flavors the milk; as of the early 1980s, suggested control methods included the use of 3,6 dichloropicolinic acid or herbicide mixtures containing diclorprop or mecoprop (Warwick and Black 1982). However, although the U&A has experienced much land conversion, rangeland is uncommon.

7.2.4 Sea level

Depending on current land use in parts of the U&A areas particularly sensitive to rising sea levels, these could favor the expansion of estuarine marshes which, as Lone Fight (2014) points out, can be home to significant numbers of traditional women's plant species. Thus, further examination of these five areas in the U&A might be of particular interest for the PGST.

7.3 Memory and resilience

The creation of images, stories, songs, and dances are traditional ways of lifting up events and perspectives to ensure cultural transmission of important memories. One could argue that one of the most important elements of this research project was the creation of the image that appears on the title page of this report, reproduced again here. We commissioned this artwork from renown Coast Salish tribal artist (John Nytom, Makah), which was produced following conversations about the reasons and relevance of this research project for the Port Gamble S'Klallam Tribe. Signed prints of the image were distributed to PGST members and employees who participated in this portion of the larger project, which is the dissertation work of the second author of this report, Gail Woodside.

The beautiful image expresses many ideas. The plant around the border is Prince's Pine and is becoming harder to find. Its relationship for healing and wellbeing weaves its way through the generations of time and space. The squirrel tails plant is declining and as time progresses and change occurs it is no longer a life force for the elk or the people. The ribs are showing on the animals due to habitat loss and poor nutrition caused by changes both anthropogenically and climatically. The sky is blue denoting absence of clouds and rain, giving a false sense of acceptance. The mountains are without snow denoting that the coming change in temperature and precipitation is imminent. The people are looking out into the landscape to seek what they have gathered since time immemorial. They have always looked out into the landscape, but what they are seeing is that as change occurs what they are looking for escapes their vision. The mountain is also looking to see if it can locate what the people are seeking; its wisdom can offer no stories. The medicine wheel shows cross cultural ties between my ancestry and the ancestry of the S'Klallam people. The medicine wheel also tells a story of change, as it does not just stay in one location but travels across the landscapes to all people who are from the mother and changes their way of life as well.

Remembering the past helps understand the present and plan for the future. A clear understanding of history, how things have come to be the way they are, is an essential part of resilience. We close, then by emphasizing by reiteration material from the beginning of this report.

The people for and with whom this present research was done are the Port Gamble S'Klallam Tribe (PGST), who are known as "NUX SKLAI YEM" or the "Strong People." Today, the people are asking what they should learn from their ancestors to be able to understand the problems that develop in today's world and how to prepare for the future (DeCoteau and Waterhouse Jr. 2013). DeCoteau and Waterhouse state:

> *"It has been said that mankind is incapable of learning from the past. This may be true for western or white society, but it is not true for Native American people. The very essence of our traditional culture demands that knowledge acquired in the past be passed on to each succeeding generation by the elders of the time. In this manner our culture has survived many years of oppression and social change."*

For these reasons we came to the elders to discuss their concerns for future change, to preserve oral traditions and ways of knowing, and to understand how to implement this knowledge to help educate the future generations.

Specific concerns have been expressed by elders and cultural coaches in regard to preserving and/or restoring cultural lifeways. Across the Pacific Northwest tribal people have come together to discuss and direct research and preserve knowledge. It is here that building relationships with western scientists and traditional people come together to figure out ways to preserve and prepare.

8 CONCLUSIONS AND RECOMMENDATIONS

This short project has taught us many things.

1. The proposed timeline for completion of such a complex endeavor was entirely inadequate, especially given that the first step was the creation of a Memorandum of Understanding that satisfied all parties, including its necessary correspondence with Oregon State University's Institutional Review Board certification. In fact, the MOU is more stringent than our IRB certification, but the process of creating the MOU informed our IRB process, even though it took longer to complete.
2. We strongly recommend that scientists wishing to work in partnership with tribes consider adding the formulation of a formal MOU to project planning. Collaborative creation of this document at a thoughtful and considered pace was invaluable in helping us resolve various issues that emerged over the course of the project in a reasonably straightforward manner. We cannot emphasize strongly enough how crucial we feel such a process to be.
3. One of the most temporally intensive parts of this research was preparing for, arranging, and carrying out the invaluable interactions with PGST elders, whose thoughtful consideration of culturally important plants and their current status in the U&A formed both the reason for as well as the essential foundation of this research, which comprises just one element of second author Gail Woodside's dissertation research.
4. Cultural products, such as the image commissioned for this research, can be significant for cultural transmission of matters of importance.
5. The very short fuse on this project meant that the final report was submitted to USGS before presentation to the PGST community, although it has undergone preliminary tribal review to ensure that matters of cultural sensitivity are appropriately treated. We do not recommend this sequencing of events.
6. This research essentially comprises a pilot study, and creates a working baseline for future investigations of culturally sensitive plants.
7. Eight terrestrial focal species of key cultural concern were identified, however….
8. Due to time constraints, correspondence between Linnaean and Indigenous taxonomies has not been thoroughly evaluated.
9. Elders report that two perennial weedy species of broad ecological amplitude (cattail and yarrow) are among the eight culturally important species that have become relatively rare in the U&A. This astonishing fact, which is consistent with our own subsequent reconnaissance in traditional gathering areas, deserves further attention.
10. Potential impacts of changing climates on the eight focal species of key cultural concern are unclear, although some of the information from the scientific literature may prove useful to PGST elders and resource managers.
11. Anticipated rises in sea level may benefit culturally important estuarine species, depending on the current and future land use and ownership of areas expected to be inundated.

9 MANAGEMENT APPLICATIONS AND PRODUCTS

One of the anticipated activities under this funding was presentation of these findings to interested community members of the Port Gamble S'Klallam Tribe, and to collaboratively engage (if/as this were deemed useful by the PGST) in developing management responses. However, the implementation of such an activity at this early stage would be at best premature. Instead, we anticipate that community presentation of parts of this research, along with consideration of the implications of these results by interested tribal members and staff, will be occur during the final stages of the second author's dissertation program.

One obvious use of this pilot project is to structure restoration activities. However, restoration planning may require that taxonomic issues, both Linnaean taxonomy as well as the correspondence between Indigenous and Linnaean taxonomies, are adequately addressed.

10 OUTREACH

Ford, J. and G. Woodside. 2013. (September) "Pulse, press, resilience, and surprise: Recognizing climate change and its effects in indigenous culture". Presentation to ESAC. Portland, OR

Woodside, G. and M.J. Jones. 2014. (May) Presentation of proposed project and listening to PGST elders, Kingston, WA.

Woodside, G., L. Lone Fight, D. Sharp, C. Rose, and J. Ford. 2015 (August). Changes in our story: Traditional and Western discussions of change and how it affects subsistence gathering for the Port Gamble S'Klallam Tribe. Organized Oral Session 29, Ecological Society of America 100th (Centennial) Annual Meeting, Baltimore, MD.

LITERATURE CITED

Abatzoglou, J.T. and T..J Brown. 2011. A comparison of statistical downscaling methods suited for wildfire applications. *International Journal of Climatology* 32(5):772-780.

Anon, 2014. The Climate CIRCulator. http://us2.campaign-archive2.com/?u=a22b31f4eb26728d57ef106b8&id=ed48b46690. 25 January 2015

Asamoah, S.A. and E.W. Bork. 2010. Drought tolerance thresholds in cattail (*Typha latifolia*): A test using controlled hydrologic treatments. *Wetlands* 30(1):99-110.

Beaubien, E. and A Hamann. 2011. Spring flowering response to climate change between 1936 and 2006 in Alberta, Canada. *Bioscience* 61:514-524.

Brubaker, L.B. 1991. Climate change and the origin of old-growth Douglas-fir forests in Puget Sound lowland. Wildlife and vegetation of unmanaged Douglas-fir forests. USDA Forest Service, General Technical Report PNW-GTR-285. Pp. 17-24. Pacific Northwest Research Station, Portland.

Busing, R.T., C.B. Halpern, and T.A. Spies. 1995. Ecology of Pacific Yew (*Taxus brevifolia*) in Western Oregon and Washington. *Conservation Biology* 9(5):1199-1207.

County Maps of Washington. 2015. http://www.countymapsofwashington.com/

CPNH 2015. Consortium of Pacific Northwest Herbaria http://www.pnwherbaria.org/

Dalton, M.M., P.W. Mote, and A.K. Snover (eds.). 2013. Climate Change in the Northwest: Implications for Our Landscapes, Waters, and Communities. Island Press. Washington D.C. 209 pps.

Daly, C. and J. Weisburg. 1997. Average annual precipitation Washington. http://www.wrcc.dri.edu/pcpn/wa.gif

Davis, M. B. and R.G. Shaw. 2001. Range shifts and adaptive responses to Quaternary climate change. *Science* 292(5517):673-679.

DeCoteau, S. and J. Waterhouse. 2013. NUX SKLAI YEM: The Strong People. Port Gamble S'Klallam Foundation. Kingston, WA. 57 pps

Ettinger, A.K., K.R. Ford, and J. HilleRisLambers. 2011. Climate determines upper, but not lower, altitudinal range limits of Pacific Northwest conifers. *Ecology* 92:1323–1331. http://dx.doi.org/10.1890/10-1639.1

Franklin, J.F. and C.T. Dyrness. 1973. Natural Vegetation of Oregon and Washington. Corvallis, OR: Oregon State University Press. Corvallis, OR. 462 pps.

Franklin, J.F., and M.A. Hemstrom. 1981. Aspects of succession in the coniferous forests of the Pacific Northwest. Chapter 14 *in* D.C. West, H.H. Shugart, and D.B. Botkin (eds.) Forest succession: Concepts and applications. Springer New York.

Gannett, H. 1902. *The forests of Washington: a revision of estimates* (No. 5). US Government Printing Office. https://books.google.com/books?hl=en&lr=&id=EmbkAAAAMAAJ&oi=fnd&pg=PA5&dq=Kitsap+County+wildfire&ots=5hJASErk_z&sig=RjmcCbwTEclxwnr2GFevZsOOKMc#v=onepage&q&f=false

Grace, J.B. 1989. Effects of water depth on *Typha latifolia* and *Typha domingensis*. *American J. Botany* 76(5):762-768.

Grossman, Z. and A. Parker. 2012. Asserting Native Resilience: Pacific Rim Indigenous Nations Face the Climate Crisis. Oregon State University Press. Corvallis, OR. 239 pps.

Hawkins, E. and R. Sutton. 2009. The potential to narrow uncertainty in regional climate predictions. *Bull. Amer. Meteor. Soc.* 90:1095–1107.

Hermann, R.K. and D.P. Lavendar. 1990. Douglas-Fir. Pps 527-540 *in* R.M. Burns and B.H. Honkala. Silvics of North America. Vol. 1: Conifers. USDA Forest Service Agriculture Handbook 654

HillRisLambers, J., M.A. Harsch, A.K. Ettinger, K.R. Ford, and E.J. Theobold. 2013. How will biotic interactions influence climate change-induced range shifts? *Annals N. Y. Acad. Sci.* 1297:112-125.

IPCC. 2000. Intergovernmental Panel on Climate Change, Special Report on Emissions Scenarios, Summary for Policy Makers, Available at: https://www.ipcc.ch/pdf/special-reports/spm/sres-en.pdf.

IPCC. 2008. Intergovernmental Panel on Climate Change, Towards New Scenarios for Analysis of Emissions, Climate Change, Impacts, and Response Strategies, IPCC Expert Meeting Report, Technical Summary, Available at: http://www.ipcc.ch/pdf/supporting-material/expert-meeting-ts-scenarios.pdf.

Jones, J.C., J.F. Hancock, and E.H. Liu. 1979. Biochemical and morphological effects of temperature on *Typha latifolia* L. (Typhaceae) originating from different ends of a thermal gradient. I. Controlled environmental studies. *American J. Botany* 66(8): 902-908

Lesher, R.D. and J.A. Henderson. 2010. Ecology and distribution of western redcedar and Alaska yellowcedar in northwestern Washington. pp 13-18 *in* A Tale of Two Cedars: International Symposium on Western Redcedar and Yellow-cedar. Portland, OR: USDA Forest Service, Pacific Northwest Research Station. General Technical Report PNW-GTR-828.

Li, S., S.R. Pezeshki, and S. Goodwin. 2004. Effects of soil moisture regimes on photosynthesis and growth in cattail (*Typha latifolia*). *Acta Oecologica* 25:17-22.

Lillesand, T.M. and R.W. Kiefer. 1994. Remote Sensing and Image Interpretation. John Wiley & Sons, Inc. New York.

Lone Fight, L. 2014. Final report on land cover change on the Port Gamble S'Klallam reservation and Usual and Accustomed Areas using Landsat satellite imagery. Unpublished report submitted to J. Ford and G. Woodside, Oregon State University Dept. of Fisheries and Wildlife.

McNaughton, S.J. 1966. Ecotype function in the *Typha* community-type. *Ecological Monographs* 36:296-325.

_______________ 1973. Comparative photosynthesis of Quebec and California ecotypes of *Typha latifolia*. *Ecology* 54:1260-1270.

Mote, P. et al., 2008. Sea Level Rise in the Coastal Waters of Washington State, Seattle. Available at: http://cses.washington.edu/db/pdf/moteetalslr579.pdf

Mote, P., L. Brekke, P.B. Duffy, and E. Maurer, 2011, Guidelines for constructing climate scenarios. *Eos Transactions* AGU, 92(31), 257, DOI: 10.1029/2011EO310001

Mote, P.W. and E.P. Salathé. 2010. Future climate in the Pacific Northwest. *Climatic Change* 102:29–50. DOI 10.1007/s10584-010-9848-z

Mueller-Dombois, D. and H. Ellenberg. 1974. Aims and Methods of Vegetation Ecology. John Wiley & Sons. New York.

Nakawatase, J.M. and D.L. Peterson. 2006. Spatial variability in forest growth – climate relationships in the Olympic Mountains, Washington. *Canadian Journal of Forest Research* 36(1):77-91.

NOAA. 2015. http://coast.noaa.gov/slr/?redirect=301ocm

NRC (National Research Council). 2012. Sea-level rise for the coasts of California, Oregon, and Washington: Past, present, and future". Committee on Sea Level Rise in California, Oregon, and Washington, Board on Earth Sciences and Resources, and Ocean Studies

Board Division on Earth and Life Sciences national Research Council. The National Academies Press, Washington, DC.

OSUTEK. 2013. Oregon State University Traditional Ecological Knowledge Conference: Resilient Relationships across Cultural and Ecological Landscapes.

Pellant, M., P. Shaver, D.A. Pyke, J.E. Herrick. 2005. Interpreting indicators of rangeland health, version 4. Technical Reference 1734-6. US Department of the Interior, *Bureau of Land Management, National Science and Technology Center, Denver, CO*. BLM/WO/ST-00/001+ 1734/REV05.

Phillips, S.J. and M. Dudik. 2008. Modeling of species distributions with Maxent: new extensions and a comprehensive evaluation. *Ecography* 31:161-175.

Poorter, H. 1993. Interspecific variation in the growth response of plants to an elevated ambient CO_2 concentration. *Vegetatio* 104-105(1):77-97.

Pratt, D.C. and N.J. Andrews. 1980. Cattails (*Typha* spp.) as an energy source. *In* D.L. Klass and J.W. Weatherly III (eds). Energy from Biomass and Wastes IV. Inst. Gas Technol. Chicago, IL.

Pojar, J. & Mackinnon, C. 2004. Plants of the Pacific Northwest Coast: Washington, Oregon, British Columbia, and Alaska. Lone Pine Publishing, Auburn, WA. 528 PPS

PNPTC (Point No Point Treaty Council). 2015. www.http://www.pnptc.org/GIS.html

Port Gamble S'Klallam Tribe (PGST). 2015. https://www.pgst.nsn.us/

Pyke, D.A., J.E. Herrick, P. Shaver, and M. Pellant. 2002. Rangeland health attirbutes and indicators for qualitative assessment. *J. Range Management*. 55:584-597.

Reeder, W.S., P. Ruggiero, S.L. Shafer, A.K. Snover, L.L. Houston, P. Glick, J.A. Newton, and S.M. Capalbo. 2013. Coasts: Complex Changes Affecting the Northwest's Diverse Shorelines. pp. 67-109 *in* Dalton et al. 2013.

Ridolfi, C., 2013. Rising Sea Level Threatens Port Gamble Tribe. *Daily Journal of Commerce Environmental Outlook*. Available at: http//www.djc.com/news/en/12057642.html

Russell, J.H. and J. Krakowski. 2010. Yellow-cedar and western redcedar adapatation to present and future climates. pp. 65-74 *in* A Tale of Two Cedars: International Symposium on Western Redcedar and Yellow-cedar. Portland, OR: USDA Forest Service, Pacific Northwest Research Station. General Technical Report PNW-GTR-828.

Sæbø, A. and L.M. Mortensen. 1998. Influence of elevated atmospheric CO_2 concentration on common weeds in Scandinavian agriculture. *Acta Agriculturae Scandinavica*: Section B, Soil and Plant Science 48(3):138-143.

Smith, S.G. 1986. The cattails (*Typha*): Interspecific ecological differences and problems of identification. *Lake and Reservoir Management* 2:357-362.

Thompson, R.S., K.H. Anderson, R.T. Pelltier, L.E. Strickland, S.L. Shafer, and P.J. Bartlein. 2012. Atlas of relations between climatic parameters and distributions of important trees and shrubs in North America – Modern data for climatic estimation from vegetation inventories. USGS Professional Paper 1650-F. USGS, Reston, VA. http://pubs.usgs.gov/pp/p1650-f/DataTables.html

Travis, J.M.J. 2003. Climate change and habitat destruction: a deadly anthropogenic cocktail. *Proceedings of the Royal Society of London B: Biological Sciences* 270(1514):467-473.

USDA, NRCS. 2015. The PLANTS Database. 2015 http://plants.usda.gov. National Plant Data Team, Greensboro, NC 27401-4901 USA.

USEPA. 2015. Level III and IV Ecoregion of Washington. 2015 http://www.epa.gov/wed/pages/ecoregions/wa_eco.htm#Ecoregions%20denote

Warwick, S.I. and L. Black. 1982. The biology of Canadian weeds. 52. Achillea millefolium. *Can. J. Plant Science*. 62:163-182.

Wein, R.W., G. Wein, S. Bahret, and W.J. Cody. 1992. Northward invading non-native vascular plant species in and adjacent to Wood Buffalo National Park, Canada. *The Canadian Field-Naturalist* 106(2): 216-224.

Weinmann, F., P.F. Zika, D.E. Giblin, and B. Legler. 2002. Checklist of the Vascular Plants of Washington State. University of Washington Herbarium. 05 Mar 2015. http://biology.burke.washington.edu/herbarium/waflora/checklist.php

Whitlock, C. 1992. Vegetation and climate history of the Pacific Northwest during the last 20,000 years: Implications for understanding present-day biodiversity. *Northwest Environment J.* 8:5-28.

Xu Z., Z. Feng, J. Yang, J. Zheng, and F. Zhang. 2013. Nowhere to invade: *Rumex crispus* and *Typha latifolia* projected to disappear under future climate scenarios. PLoS ONE 8(7): e70728. doi:10.1371/journal.pone.0070728

Yeo, R.R. 1964. Life history of common cattail. *Weeds* 12(4):284-288.

Zhang, B., S. Xiu, and A. Shahbazi. 2012. Aquatic plants: Is it a viable source for biofuel productions? Chapter 7 (pps 203-216) *in* M.J. Acosta (ed.) Advances in Energy Research. Nova Science Publishers, Inc.

Zobel, D.B., A. McKee, and G.M. Hawk. 1976. Relationships of environment to composition, structure, and diversity of forest communities of the central western Cascades of Oregon. *Ecological Monographs* 46(2):135-156.

APPENDIX 1

Memorandum of Understanding between Oregon State University researchers and The Port Gamble S'Klallam Tribe

Memorandum of Understanding
Between the
Port Gamble S'Klallam Tribe
(hereinafter referred to as "Tribe")
and
Dr. M. Jesse Ford, Oregon State University
Gail J. Woodside MSc, Oregon State University
(hereinafter referred to as "OSU"
Collectively (the researchers), referred to herein as the "Parties"

I BACKGROUND

A. The Port Gamble S'Klallam Tribe supports and approves its participation in the collaborative project "**Vulnerability of traditional women's foods, medicinals, and plants used in material culture to climate change on the Olympic Penninsula, WA: Management projections and implications for tribal perspectives on Usual and Accustomed gathering areas**" and recognizes the value and importance of advising its Natural Resource Department's research, monitoring, restoration and management efforts with our Indigenous Traditional Knowledge from elders, hunters, fishers, and tribal leaders.

B. The Parties have entered into a collaborative research project to work towards the following goals and objectives:

a. To collect and assimilate Indigenous Traditional Knowledge about the Tribe's priority natural resources, historical populations of important subsistence species, plants of Key Cultural Significance (KCS), oral histories and knowledge about these species and the concerns of change or loss of these species due to climatic changes in Usual and Accustomed gathering areas of the Point No Point Treaty Council boundaries. This collaborative research will be focused on two threads with tribal elders, resource managers, and widsomkeepers to 1. document historic distributions of KCS species and 2. Elder/manager/wisdomkeeper assessments of the impacts of such potential changes for contemporary cultural practices.

b. To document species of key cultural significance to the PGST, compile a catalogue of ecological data for a subset of KCS species thought to be sensitive to changes in spatial and temporal patterns of aridity (e.g., wetland and tidal species). Document historical changes in distribution and abundance of this subset of KCS species. Document the range of predicted changes of key climate variables for Point No Point Treaty Council U & A gathering areas. Apply the results of climate scenarios to the ecological catalogue of key climate sensitive species of cultural significance, and determine potential implications for plant distribution and abundance across static geopolitical boundaries that currently constrain gathering and harvesting activities. Together with tribal elders, wisdomkeepers, and resource managers, develop a set of management options for addressing shifting range and abundance of plant species of key cultural significance.

c. Provide capacity building within the Tribe's Natural Resource Department that will provide future expertise for carrying out Indigenous Traditional Knowledge research, establishing connections with elders, managers, and wisdomkeepers etc..
d. Presentations for national or international professional conferences will be developed in collaboration with the PGST Natural Resources Program. One presentation will be in August 2014 for the Ecological Society of America. Other presentations will be developed with the PGST Natural Resources Program for other future conferences as they are decided upon. Some presentations may include a joint presentation with the wisdomkeeper of the Tribe.
e. Produce co-authored papers, presentations and or article(s) at conferences or in professional journals that focuses on the integration of Indigenous Traditional Knowledge and Science in sustainable natural resource management.

C. In support of these goals and objectives, the Parties will seek to combine traditional and innovative forms of research. Application of conventional scientific tools to analyze these two threads in an iterative process with tribal elders, managers, wisdomkeepers to produce a range of specific management options for addressing likely changes in access to KCS plants as a result of climate change.

D. The Port Gamble S'Klallam Tribe wishes to ensure that its people's customary stories and related teachings do not become the property of the Oregon State University, or its supported or affiliated researchers.

E. The Parties wish to carry out their goals and objectives in the context of the following principles:
   a. Respect for all partners involved, especially tribal elders and leaders
   b. Transparency in all dealings with respect to the research project
   c. Observation of and respect for the Tribe's cultural customs and practices.
   d. The Tribe, and its members hold dear the guardianship of their traditional knowledge, values, culture and customs
   e. The Tribe must be appropriately acknowledged, compensated and respected for such knowledge in a manner that feels both ethical and fair to them.

In honor of these and other ethical principles, the Oregon State University and its supported or affiliated researchers agree not to attempt direct acquisition of any intellectual property rights, artifacts and or royalties from publishing materials containing stories, myths, legends, folklore, oral traditions, or other traditional knowledge. Collaborative decision-making between the parties to insure that no products of this research are published, sold or otherwise provided to the public without express consent

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of the Tribe with full recognition of the Tribe and any of its members that participated.

II THEREFORE, THE PARTIES HAVE THE FOLLOWING UNDERSTANDING:

Process

A mutually agreed-on process will be followed to prioritize the specific projects done to reach the goals and objectives outlined above. For any project, this process shall minimally include:

a) Development of an academic- and community- informed project research plan (including budget), with explicit reference being made in the plan as to how the project will contribute to the Parties' broader goals and objectives. The funded USGS proposal 7/1/2013 satisfies this requirement.

Informed Consent

The informed consent of individual community members must be secured in writing before they participate in research or recordings. The written permission of the individual community members to release the information to the Port Gamble S'Klallam Tribe will be sought by the researchers, including any restrictions the individual community members [redacted] Gamble S'Klallam Tribe. Copies of all audio/visual recordings and originals of notes, transcripts, photographs and other records will be kept by the researchers.

The Parties will ensure that a final, permanent repository for the research materials, to be created by the researchers, will be utilized. Additionally, the researchers will make as a condition of the deposition that the repository will provide access to Port Gamble S'Klallam Tribe members. Further, the repository will adhere to any confidentiality or use restrictions made by the individual community members under section two of this Memorandum.

Protection of Customary Intangible Property

The Parties agree that the researchers will respect customary Port Gamble S'Klallam property laws. To facilitate this, the Parties agree that the researchers will endeavour to, where reasonably possible, generally record without unnecessary specifics, known customary intangible properties, respecting private and confidential sacred matters ("Customary

Intangible Property" and or "Intellectual Property Rights").

The Parties recognize that the Port Gamble S'Klallam elders may provide guidance and advice in identifying and delimiting Customary Intangible Property and or Intellectual Property Rights.

Publication

Subject to the terms of the arrangement set out in this Memorandum of Understanding, the Port Gamble S'Klallam Tribe hereby grants the researchers permission to publish for scholarly and educational purposes the information collected during the course of the research project.

The researchers will ensure that two copies of all publications, conference papers and other educational and scholarly materials produced in the course of the project be deposited with the Port Gamble S'Klallam Tribe.

Ownership of Customary Intangible Property

In publications resulting from this collaborative arrangement, no claim of copyright or exclusive rights by the researchers or their publishers will be made on legends, myths, folklore or that are the acknowledged intellectual property of the Port Gamble S'Klallam community or community members.

Any publication done for scholarly and/or educational purposes will include the following provision: "The text of the stories, myths, legends, and folklore belong to the Port Gamble S'Klallam people and therefore no claim of copyright or exclusive rights is made upon them."

Confidentiality and Royalties

The Parties agree that where Customary Intangible Property and or Intellectual Property, referred to above in this Memorandum of Understanding, is inappropriately shared with the researchers, taken without permission or mistakenly recorded by them, they will use all reasonable efforts to prevent the publication of, or public access to, this information.

The Parties will not acquire any royalties or monies tantamount to royalties for publishing materials that contain Port Gamble S'Klallam stories, myths, legends, folklore, or either Customary Intangible or Intellectual Property. This does not constrain the researchers from publishing and collecting royalties from mutually agreed to, case by case, addendums to this MOU, each case of which would require specific approvals from each Party.

Dispute Resolution

In case of a dispute arising from the implementation of this Memorandum of Understanding, the Parties shall exhaust alternative dispute resolution models such as negotiation and mediation before employing other forms of dispute resolution such as arbitration or adjudication. Parties shall act in good faith to resolve any disputes.

In the case of a dispute arising regarding the proper management of Customary Intangible or Intellectual Property, the Tribe and or elders shall specify the means for settling the dispute, such as mediation.

Insurance

The parties acknowledge that they have adequate liability insurance applicable to their officers, employees, and agents while acting within the scope of their employment by the parties. Therefore, each party hereby assumes any risks of personal injury and property damage attributable to the negligent acts or omissions of the party and its officers, employees, and agents.

Notification

Any notice of written communication required under this agreement may be given as follows:

Port Gamble S'Klallam Tribe:
31912 Little Boston Road NE, Kingston, Washington 98346
Phone: 360/297-2646, Fax: 360/297-7097

Oregon State University:
Dr. Jesse Ford, Associate Professor
Department of Fisheries and Wildlife
104 Nash Hall, Corvallis, OR 97331-3803
Phone: 541-737-1960, Fax: 541-737-1980, cell 541-740-9953

Amendments

Amendments to this Memorandum of Understanding must be in writing and signed by authorized representatives of the Port Gamble S'Klallam Tribe and the Oregon State [redacted]

Duration of Agreement

The term of this Memorandum of Understanding is from December 4, 2013 to December 3, 2015. The Parties will review this agreement annually with any proposed amendments requiring agreement from both parties.

The Parties may terminate this Memorandum of Understanding in writing at any time subject to 60 days notice.

SIGNED BY THE PARTIES ON THE DATES SET OUT BELOW

Signature: PGST:	Jeromy Sullivan, Chairman	Date: Dec 17, 2013
Signature: OSU:	M. Jesse Ford Oregon State University	Date: Dec 16 2013
Signature: OSU:	Gail J. Woodside Oregon State University	Date: Dec 16, 2013

APPENDIX 2

Search strategy
and
climate-related citations for eight focal species

Cascara (*Frangula purshiana*)
Wetland status: FAC

Searches

-Agricola: Frangula purshiana, Rhamnus purshiana
-CAB Abstracts: Frangula purshiana, Rhamnus purshiana – some pharmacological/medicinal lit available. Also lit on horticulture.
-Google Scholar: Frangula purshiana (too broad), Frangula purshiana/climate , Rhamnus purshiana/climate, Frangula purshiana/temperature, Rhamnus purshiana/temperature
-ProQuest Environmental Science and Pollution Management: Frangula purshiana, Rhamnus purshiana
-TreeSearch: Frangula purshiana, Rhamnus purshiana
-Web of Science: Frangula purshiana, Rhamnus purshiana – some pharmacological/medicinal lit available
-Wildlife and Ecology Studies Worldwide: Frangula purshiana, Rhamnus purshiana

Cattail/Broadleaf cattail (*Typha latifolia*)
Wetland status: OBL

Searches

-Agricola: Typha latifolia (too broad – lots of contaminants hits), Typha latifolia/climate, Typha latifolia/precipitation, cattail/climate, cattail/precipitation, cattail/moisture, Typha latifolia/moisture, Typha latifolia/hydrology
-CAB Abstracts: Typha latifolia – a lot of toxicology lit. Typha latifolia/climate, Typha latifolia/moisture, Typha latifolia/temperature
-ProQuest Environmental Science and Pollution Management: Typha latifolia/climate – mostly related to wastewater treatment
-Web of Science: Typha latifolia – abundant literature on use for heavy metal/toxin removal from soil and wastewater treatment
-Wildlife and Ecology Studies Worldwide: Typha latifolia/climate

Asamoah, SA and EW Bork. 2010. Drought tolerance thresholds in cattail (*Typha latifolia*): A test using controlled hydrologic treatments. Wetlands 30(1):99-110.
-Available at: http://link.springer.com/article/10.1007/s13157-009-0005-2

Grace, JB. 1989. Effects of water depth on *Typha latifolia* and *Typha domingensis*. American Journal of Botany 76(5):762-768.
-Available at: http://www.jstor.org/stable/2444423?origin=crossref&seq=1#page_scan_tab_contents

Jones, JC, JF Hancock, and EH Liu. 1979. Biochemical and morphological effects of temperature on Typha latifolia L. (Typhaceae) originating from different ends of a thermal gradient. Amer. J. Bot. 66(8): 902-906.
-Available at: http://www.jstor.org/stable/2442230?origin=crossref&seq=1#page_scan_tab_contents
-Includes effects of temperature on growth

Li, S, SR Pezeshki, and S Goodwin. 2004. Effects of soil moisture regimes on photosynthesis and growth in cattail (Typha latifolia). Acta Oecologica 25:17-22.
-Available at: http://www.sciencedirect.com/science/article/pii/S1146609X03001139

Xu, Z, Z Feng, J Yang, J Zheng, and F Zhang. 2013. Nowhere to invade: *Rumex crispus* and *Typha latifolia* projected to disappear under future climate scenarios. PLoS ONE 8(7): e70728.
-Available at: http://web.a.ebscohost.com/ehost/detail/detail?sid=ede4d80a-c42d-407f-8354-269d762a054b%40sessionmgr4002&vid=0&hid=4112&bdata=JnNpdGU9ZWhvc3QtbGl2ZQ%3d%3d#db=aph&AN=89629098
-Written from invasive species perspective, but includes effects of climate change on *Typha latifolia* growth and distribution.

Common yarrow/Squirrel Tail (*Achillea millefolium*)
Wetland status: FACU

Searches

-Agricola: Achillea millefolium (too broad – mostly chemical), Achillea millefolium/climate, Achillea millefolium/precipitation, Achillea millefolium/moisture, Achillea millefolium/temperature, Achillea millefolium/hydrology
-CAB Abstracts: Achillea millefolium (too broad), Achillea millefolium/climate, Achillea millefolium/temperature
-Google Scholar: Achillea millefolium/climate
-ProQuest Environmental Science and Pollution Management: Achillea millefolium/climate
-Web of Science: Achillea millefolium – abundant pharmacological/medicinal lit
-Wildlife and Ecology Studies Worldwide: Achillea millefolium

Arne, S and LM Mortensen. 1998. Influence of elevated atmospheric CO_2 concentration on common weeds in Scandinavian agriculture. Acta Agriculturae Scandinavica: Section B, Soil and Plant Science 48(3):138-143.
-Available at: http://web.a.ebscohost.com/ehost/detail/detail?sid=a6a32900-3fcc-4ecf-ad16-807168b475b8%40sessionmgr4005&vid=0&hid=4112&bdata=JnNpdGU9ZWhvc3QtbGl2ZQ%3d%3d#db=aph&AN=6670250

Beaubien, E and A Hamann. 2011. Spring flowering response to climate change between 1936 and 2006 in Alberta, Canada. Bioscience 61:514-524.
-Available at: http://bioscience.oxfordjournals.org/content/61/7/514.full.pdf+html
-Yarrow a focus species in studies

Warwick, SI and L Black. 1982. The biology of Canadian weeds. 52. Achillea millefolium. Can. J. Plant Science. 62:163-182.
-Available at: http://pubs.aic.ca/doi/abs/10.4141/cjps82-024
-Includes response to temperature and moisture

Wein, RW, G. Wein, S. Bahret, and WJ Cody. 1992. Northward invading non-native vascular plant species in and adjacent to Wood Buffalo National Park, Canada. The Canadian Field-Naturalist 106(2): 216-224.
-Available at: http://www.biodiversitylibrary.org/item/106990#page/5/mode/1up
-Yarrow a focus species in study

Devil's Club (*Oplopanax horridus*)
Wetland Status: FAC

Searches

-Agricola: Oplopanax horridus – nothing relevant
-CAB Abstracts: Oplopanax horridus – most pharmacological/medicinal, Oplopanax (refined to Forests, Plant Ecology, Meteorology and Climate)
-Google Scholar: devil's club/temperature, devil's club/temperature/range, devil's club/precipitation, devil's club/climate, Olympic/vegetation/distribution[too broad], Olympic/Oplopanax/distribution, Oplopanax/distribution/climate, Oplopanax/range/temperature, Oplopanax/precipitation, Oplopanax/moisture, Oplopanax/environmental conditions (3 items)
-TreeSearch (Forest Service): none
-Web of Science: Oplopanax horridus – pharmacological/medical lit. available
-Wildlife and Ecology Studies Worldwide: Oplopanax horridus

Lantz, TC and JA Antos. 2002. Clonal expansion in the deciduous understory shrub, devil's club (*Oplopanax horridus*). Canadian Journal of Botany 80(10): 1052-1062.
-Available at: http://www.cabdirect.org/abstracts/20023190271.html?resultNumber=3&q=Oplopanax+horridus&fq=cc_facet%3A%22KK100+-+Forests+and+Forest+Trees+%28Biology+and+Ecology%29%22
-May contain relevant info on environmental conditions for growth

Roorbach, AH. 1999. The ecology of devil's club (*Oplopanax horridum*) in western Oregon. Ph.D. Dissertation, Oregon State University.
-Available at : http://ir.library.oregonstate.edu/xmlui/handle/1957/11063
-includes data on soil moisture class

Sarr, DA. 2004. Multiscale controls on woody riparian vegetation: Distribution, diversity, and tree regeneration in four western Oregon watersheds. PhD Dissertation, Oregon State University.
-Available from: http://ir.library.oregonstate.edu/xmlui/handle/1957/11106
-analyses of multi-scale controls on diversity, distribution, and regeneration included devil's club

Thompson, RS, KH Anderson, LE Strickland, SL Shafer, RT Pelltier, and PJ Bartlein. 2006. Atlas of relations between climatic parameters and distributions of important trees and shrubs in North America – Alaska Species and Ecoregions. USGS Professional Paper 1650-D. USGS, Reston, VA.
-Available at: http://pubs.usgs.gov/pp/p1650-d/
-has mean temp and mean precip data for Alaska

Pacific yew (Taxus brevifolia)
Wetland status: FACU

Searches

-Agricola: Taxus brevifolia/precipitation, Taxus brevifolia/moisture, Taxus brevifolia/hydrology, Taxus brevifolia/temperature, Taxus brevifolia/climate
-CAB Abstracts: Taxus brevifolia/climate, Taxus brevifolia/moisture, Taxus brevifolia/precipitation, Taxus brevifolia/temperature
-Google Scholar: Taxus brevifolia/climate, Taxus brevifolia/precipitation, Taxus brevifolia/moisture, Taxus brevifolia/temperature
-ProQuest Environmental Science and Pollution Management: Taxus brevifolia
-Web of Science: Taxus brevifolia, Taxus brevifolia/moisture, Taxus brevifolia/temperature – abundant medical/pharmaceutical lit
-Wildlife and Ecology Studies Worldwide: Taxus brevifolia

Bailey, JD and LH Liegel. 1998. Pacific Yew (Taxus brevifolia) growth and site factors in western Oregon. Northwest Science 72(4):283-292.
-Available at: http://research.wsulibs.wsu.edu/xmlui/bitstream/handle/2376/1205/v72%20p283%20Bailey%20and%20Liegel.PDF?sequence=1

Busing, RT, CB Halpern, and TA Spies. 1995. Ecology of Pacific yew (*Taxus brevifolia*) in Western Oregon and Washington. Conservation Biology 9(5):1199-1207.
-Available at: http://www.jstor.org/stable/2387057?seq=1#page_scan_tab_contents

Prince's pine (*Chimaphila umbellata*)
Wetland status: UPL

Searches

-Agricola: Chimaphila umbellata, Chimaphila menziesii – nothing relevant
-CAB Abstracts: Chimaphila umbellata, Chimaphila menziesii – nothing relevant
-Google Scholar: prince's pine/temperature, *Chimaphila*/temperature, prince's pine/precipitation, *Chimaphila* precipitation, Chimaphila umbellata/climate
-ProQuest Environmental Science and Pollution Management: Chimaphila umbellata
-Web of Science: Chimaphila umbellata, Chimaphila menziesii – a few medicinal/pharmaceutical citations
-Wildlife and Ecology Studies Worldwide: Chimaphila umbellata

Sarr, DA. 2004. Multiscale controls on woody riparian vegetation: Distribution, diversity, and tree regeneration in four western Oregon watersheds. PhD Dissertation, Oregon State University.
-Available from: http://ir.library.oregonstate.edu/xmlui/handle/1957/11106
-analyses of multi-scale controls on diversity, distribution, and regeneration included prince's pine

Sxusem berries/Buffaloberry (*Shepherdia canadensis*)
Wetland status: UPL

Searches

-Agricola: Shepherdia canadensis – no climate lit; some papers on herbal/medicinal uses
-CAB Abstracts: Shepherdia canadensis, Shepherdia argentea
-Google Scholar: Buffaloberry/temperature, *Shepherdia*/temperature, Buffaloberry/precipitation, *Shepherdia*/precipitation, Shepherdia canadensis/climate, Shepherdia argentea
-ProQuest Environmental Science and Pollution Management: Shepherdia canadensis
-Web of Science: Shepherdia Canadensis, Shepherdia argentea – no medicinal/pharmaceutical lit
-Wildlife and Ecology Studies Worldwide: Shepherdia canadensis

Krebs, CJ, R Boonstra, K Cowcill, and AJ Kenney. 2009. Climatic determinants of berry crops in the boreal forest of the southwestern Yukon. Botany 87(4): 401-408.
-Available at: http://www.nrcresearchpress.com/doi/abs/10.1139/B09-013#.VOJgoC6WYb4
-found berry crops could be predicted by previous season's rainfall

Thompson, RS, KH Anderson, LE Strickland, SL Shafer, RT Pelltier, and PJ Bartlein. 2006. Atlas of relations between climatic parameters and distributions of important trees and shrubs in North America – Alaska Species and Ecoregions. USGS Professional Paper 1650-D. USGS, Reston, VA.
-Available at: http://pubs.usgs.gov/pp/p1650-d/
-has mean temp and precip data for Alaska

Western redcedar (*Thuja plicata*)
Wetland status: FAC

Searches

-Agricola: Thuja plicata/climate, Thuja plicata/temperature, Thuja plicata/moisture, Thuja plicata/precipitation, Thuja plicata/hydrology
-CAB Abstracts: Thuja plicata/climate
-Google Scholar/CAB Abstracts: western redcedar/temperature, western redcedar/precipitation (also *Thuja* and "red cedar")
-Web of Science: Thuja plicata (too broad), Thuja plicata/moisture, Thuja plicata/hydrology, Thuja plicata/temperature, Thuja plicata/climate – no medical/pharmaceutical records

Carter, R. E., & Klinka, K. (1992). Variation in shade tolerance of Douglas fir, western hemlock, and western red cedar in coastal British Columbia. *Forest Ecology and Management*, *55*(1), 87-105.
-Available at library (on paper)
-studied shade tolerance of western redcedar and several other tree species across a range of moisture conditions. In BC.

Drever, RC and KP Lertzman. 2001. Light-growth responses of coastal Douglas-fir and western redcedar saplings under different regimes of soil moisture and nutrients. Can. J. For. Res. 31:2124-2133.

-Available from: http://www.nrcresearchpress.com/doi/abs/10.1139/x01-149#.VE_tTxZyC2o
-growth/response to light across different soil moisture and nutrient regimes

Ettinger, AK, KR Ford, and J HilleRisLambers. 2011. Climate determines upper, but not lower, altitudinal range limits of Pacific Northwest conifers. Ecology 92(6):1323-1331.
-Available at: http://www.esajournals.org/doi/abs/10.1890/10-1639.1
-climate effects on growth at low-elevation were weak

Fan, S., SC Grossnickle, and JH Russell. 2008. Morphological and physiological variation in western redcedar (*Thuja plicata*) populations under contrasting soil water conditions. Trees 22:671-683.
-Available from: http://link.springer.com/article/10.1007/s00468-008-0225-8#page-1
-annual and summer precipitation vs. height and biomass increments and transpiration efficiency
-concludes that genetic variation is not indicative of adaptation to precipitation
-when soil drought was applied as a treatment, it masked physiological difference in redcedar seedlings, demonstrating western redcedar's intolerance to water stress.

Gray, LK, JH Russell, AD Yanchuk, and BJ Hawkins. 2013. Predicting the risk of cedar leaf blight (*Didymascella thujina*) in British Columbia under future climate change. Agricultural and Forest Meteorology **180**:152-163.
-Available from: http://www.sciencedirect.com/science/article/pii/S0168192313001007

Grossnickle, SC and JH Russell. 2006. Yellow-cedar and western redcedar ecophysiological response to fall, winter and early spring temperature conditions. Ann. For. Sci. **63**:1-8.
-Available from: http://www.afs-journal.org/articles/forest/abs/2006/01/F6001/F6001.html
-shows net photosynthesis as a response to minimum air temperature

Hamann, A and T Wan

Laroque, CP and DJ Smith. 2004. Predicted short-term radial-growth changes of trees based on past climate on Vancouver Island, British Columbia. Dendrochronologia 22(3):163-168.
-Available at: http://www.sciencedirect.com/science/article/pii/S1125786505000287

Sarr, DA. 2004. Multiscale controls on woody riparian vegetation: Distribution, diversity, and tree regeneration in four western Oregon watersheds. PhD Dissertation, Oregon State University.
-Available from: http://ir.library.oregonstate.edu/xmlui/handle/1957/11106
-analyses of multi-scale controls on diversity, distribution, and regeneration included western redcedar

Thompson, RS, KH Anderson, LE Strickland, SL Shafer, RT Pelltier, and PJ Bartlein. 2006. Atlas of relations between climatic parameters and distributions of important trees and shrubs in North America – Alaska Species and Ecoregions. USGS Professional Paper 1650-D. USGS, Reston, VA.
-Available at: http://pubs.usgs.gov/pp/p1650-d/
-has mean temp and mean precip data for Alaska

Thompson, RS, KH Anderson, and PJ Bartlein. 1999. Atlas of relations between climatic parameters and distributions of important trees and shrubs in North America – Introduction and conifers. USGS Professional Paper 1650-A. USGS, Reston, VA.
-Available at: http://pubs.usgs.gov/pp/p1650-a/
-has mean temp and precip data

Thompson, RS, KH Anderson, RT Pelltier, LE Strickland, SL Shafer, and PJ Bartlein. 2012. Atlas of relations between climatic parameters and distributions of important trees and shrubs in North America – Modern data for climatic estimation from vegetation inventories. USGS Professional Paper 1650-F. USGS, Reston, VA.
-includes temp and precip datasets for Thuja plicata
- http://pubs.usgs.gov/pp/p1650-f/DataTables.html

USDA. 2010. A tale of two cedars: International symposium on western redcedar and yellow-cedar. USDA Forest Service General Technical Report PNW-GTR-828.
-Articles of interest:
- ECOPHYSIOLOGICAL PROCESSES OF WESTERN REDCEDAR (*THUJA PLICATA*) AND YELLOW-CEDAR (*CALLITROPSIS NOOTKATENSIS*)
-freezing tolerance, response to drought
- YELLOW-CEDAR AND WESTERN REDCEDAR ADAPTATION TO PRESENT AND FUTURE CLIMATES
-western redcedar had moderately strong responses to climate variables. Warm, wet conditions drove productivity. Cedar leaf blight increased with site moisture and winter warmth.
-GROWTH OF WESTERN REDCEDAR AND YELLOW-CEDAR

-redcedar productivity in response to climate variables
-Available from:
http://scholar.google.com/scholar?cluster=18223234422438719373&hl=en&as_sdt=0,38

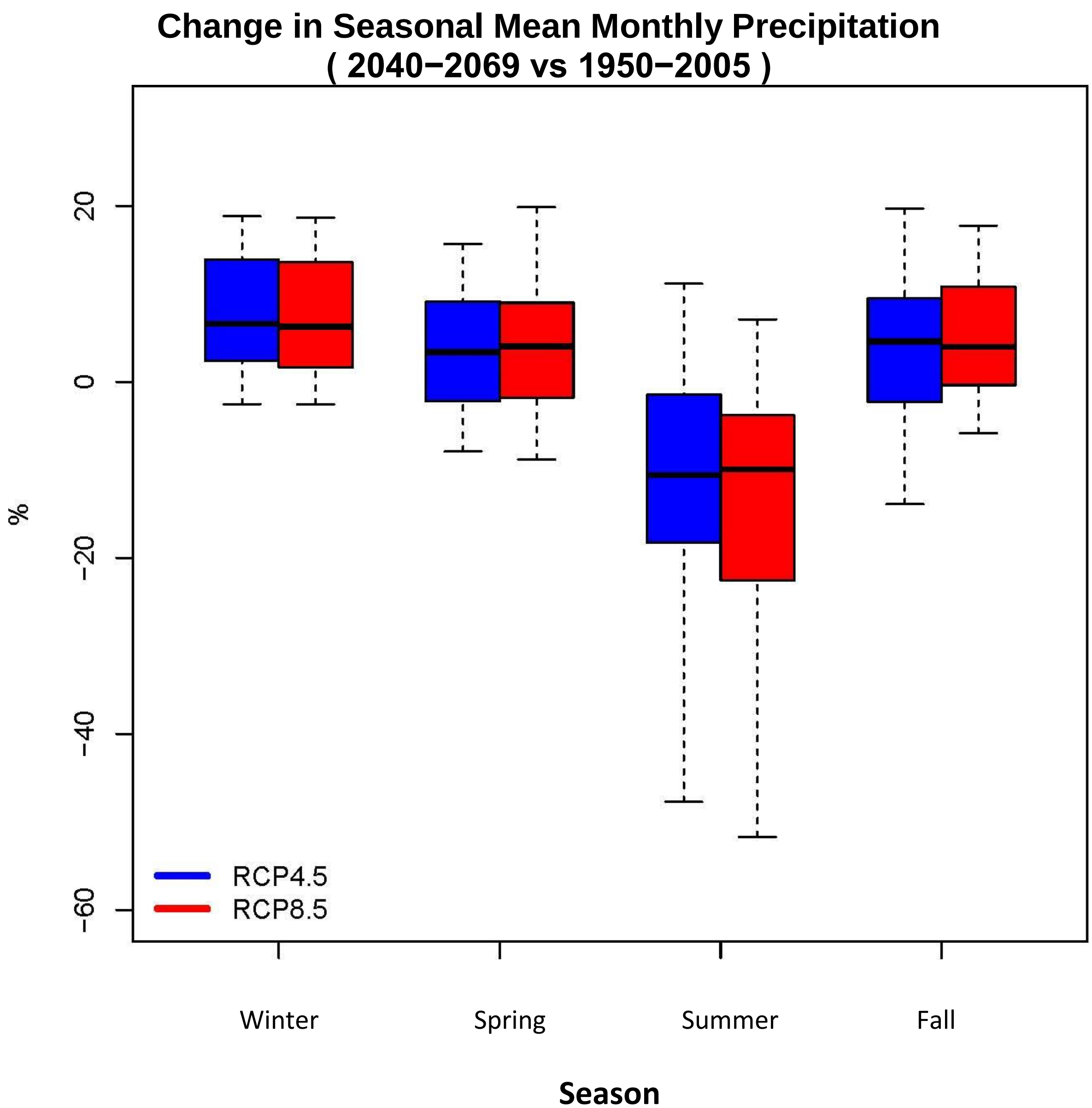
Zobel, DB, A McKee, GM Hawk, and CT Dyrness. 1976. Relationships of environment to composition, structure, and diversity of forest communities of the central western Cascades of Oregon. Ecological Monographs 46:435-156
-Available at: http://www.jstor.org/stable/1942248
-includes data table with moisture and temp ranges/gradients

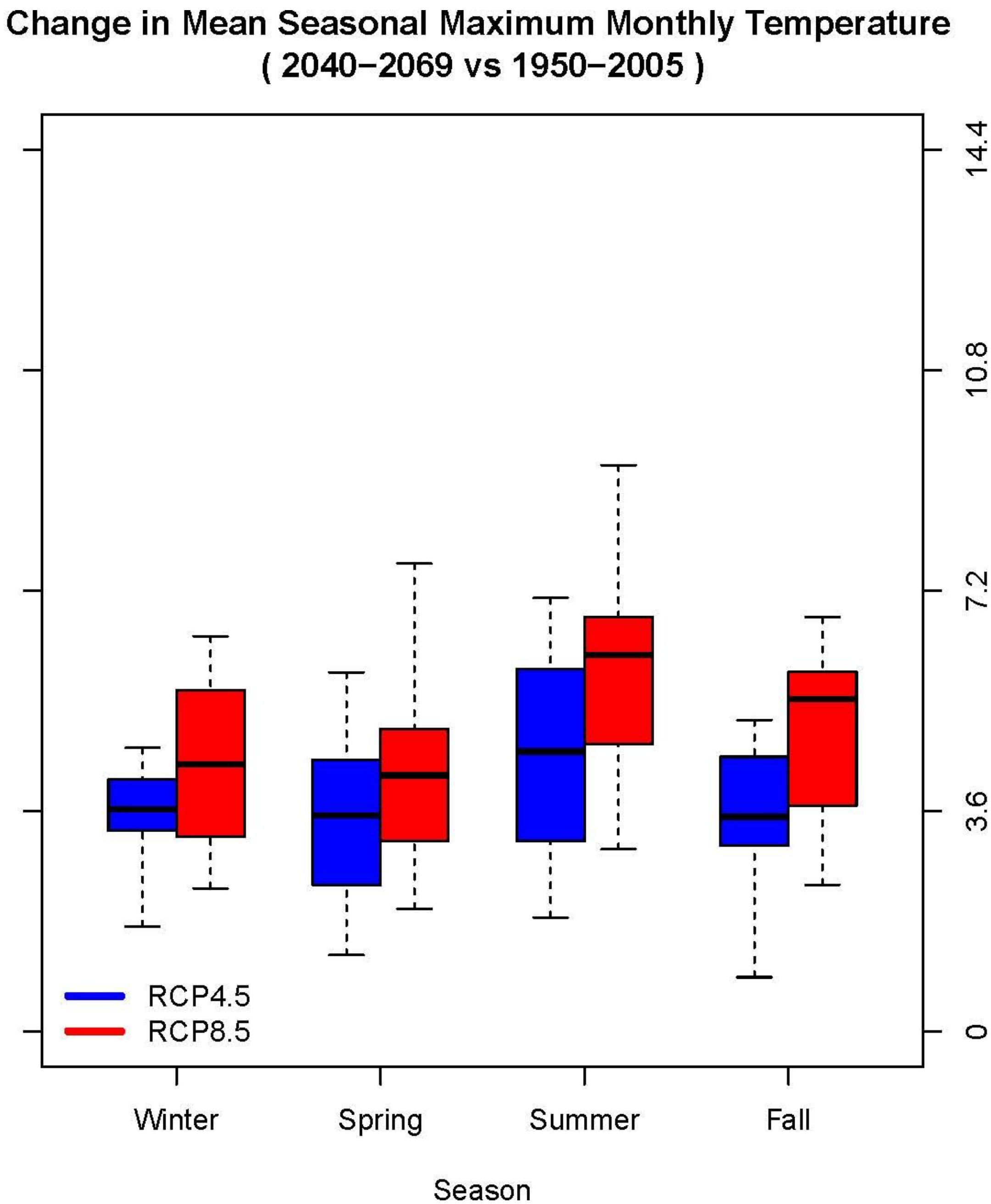
Zolbrod, AN and DL Peterson. 1999. Response of high-elevation forests in the Olympic Mountains to climatic change. Canadian Journal of Forest Resources **29**:1966-1978.
-Available at: http://www.nrcresearchpress.com/doi/abs/10.1139/x99-177
-some data on effect of climate on western redcedar

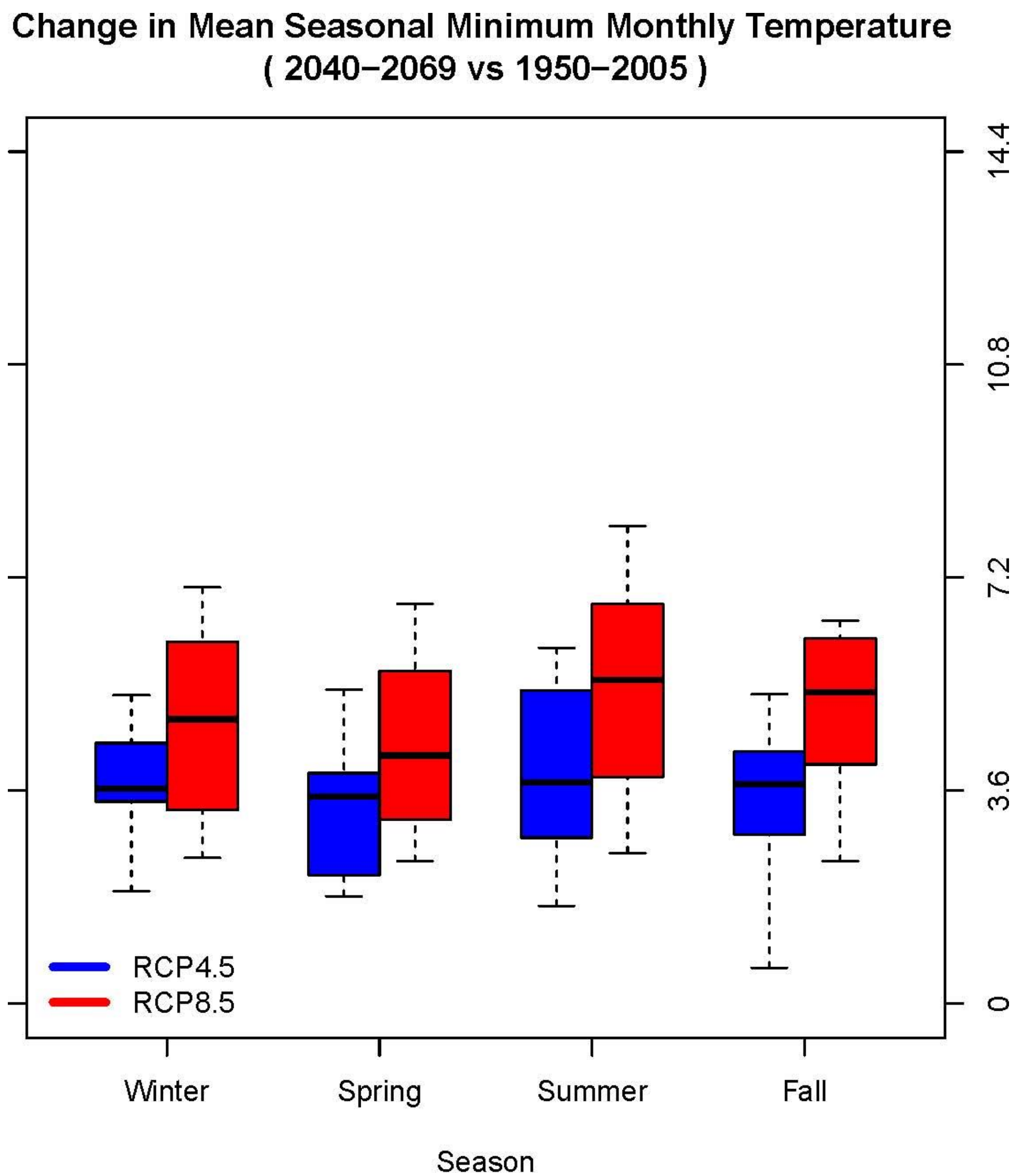
APPENDIX 3

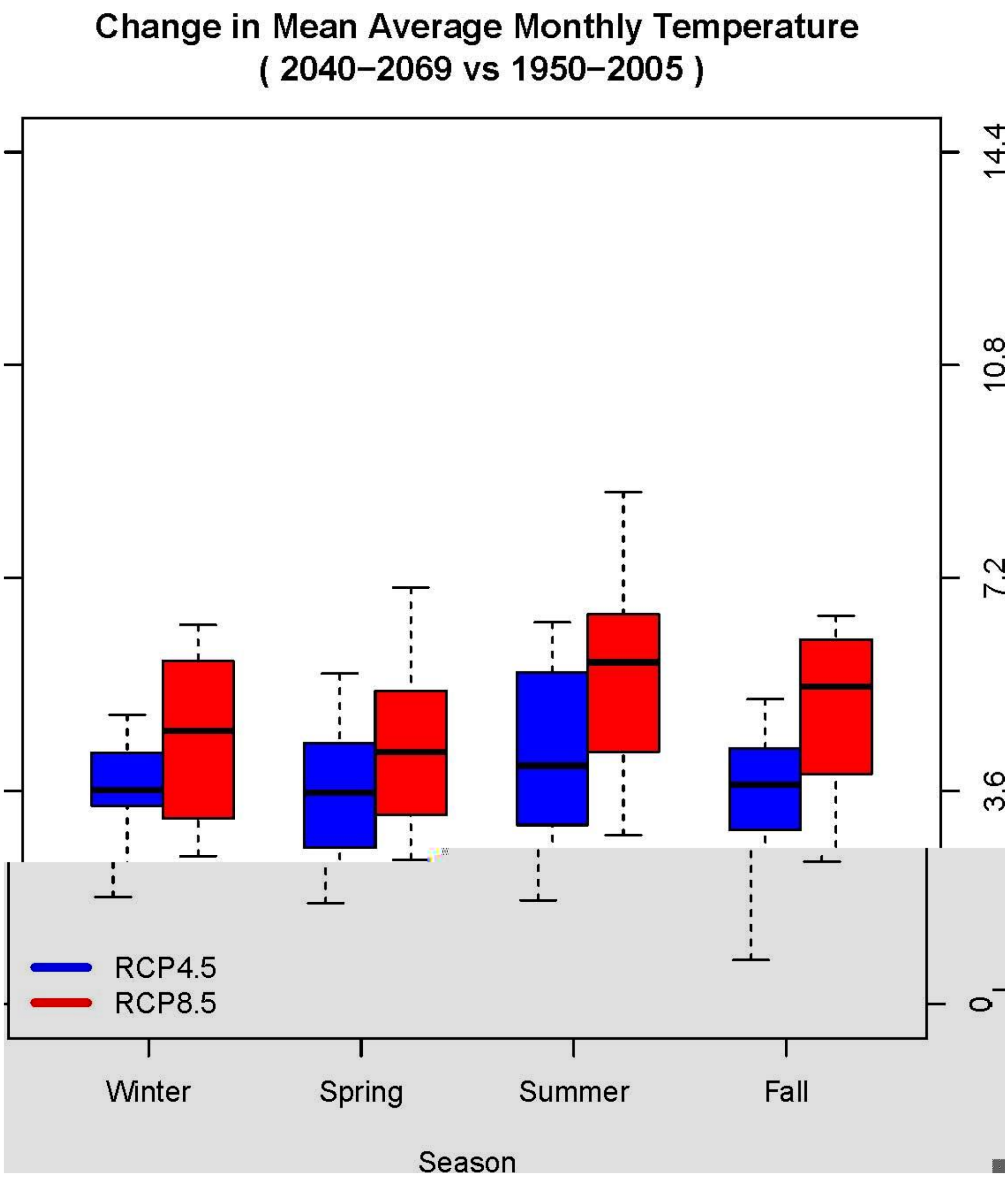
Figure 12 climate scenarios
(full-size)

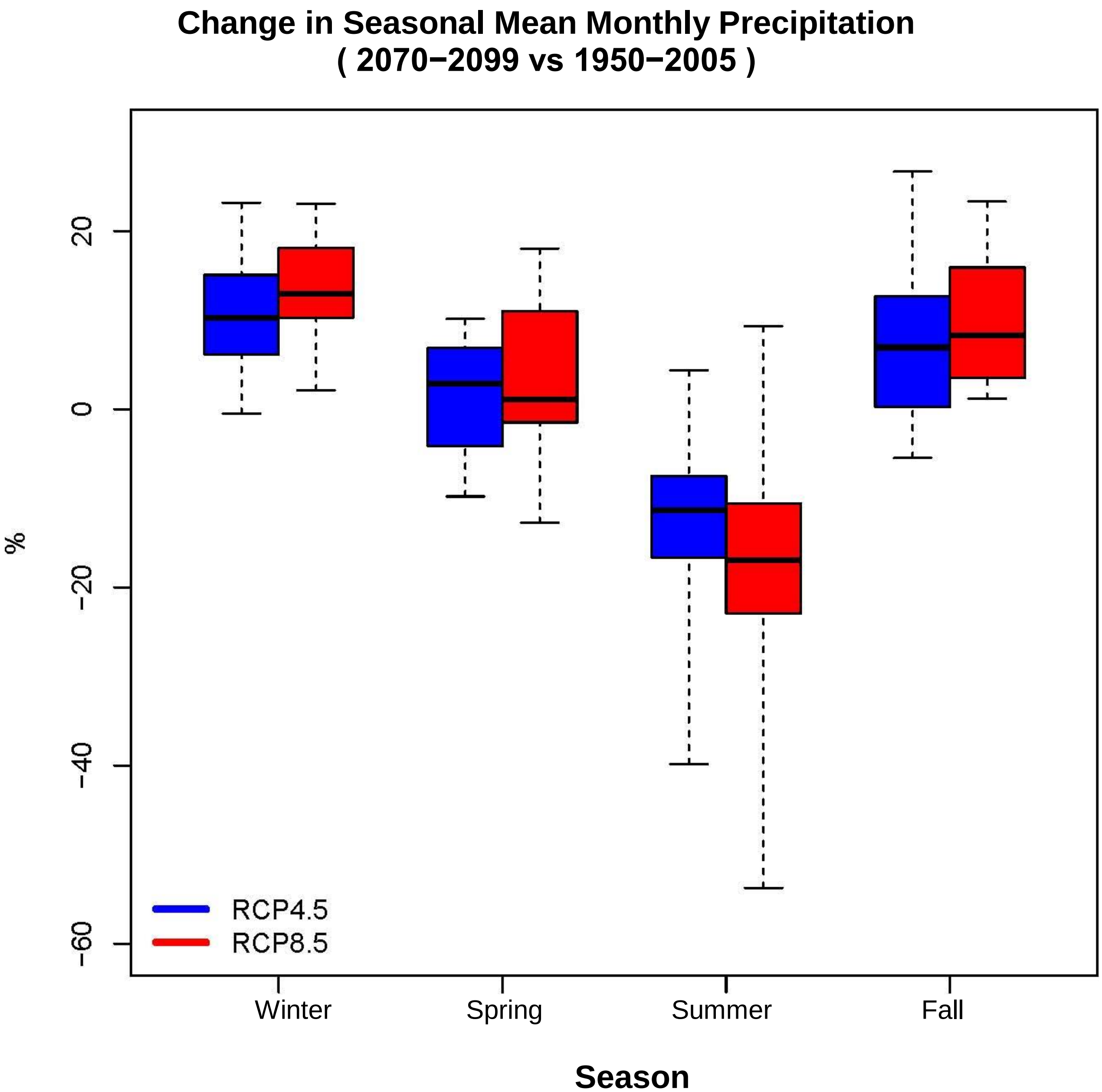
All precipitation as % of 1950-2005
All temperatures in °F

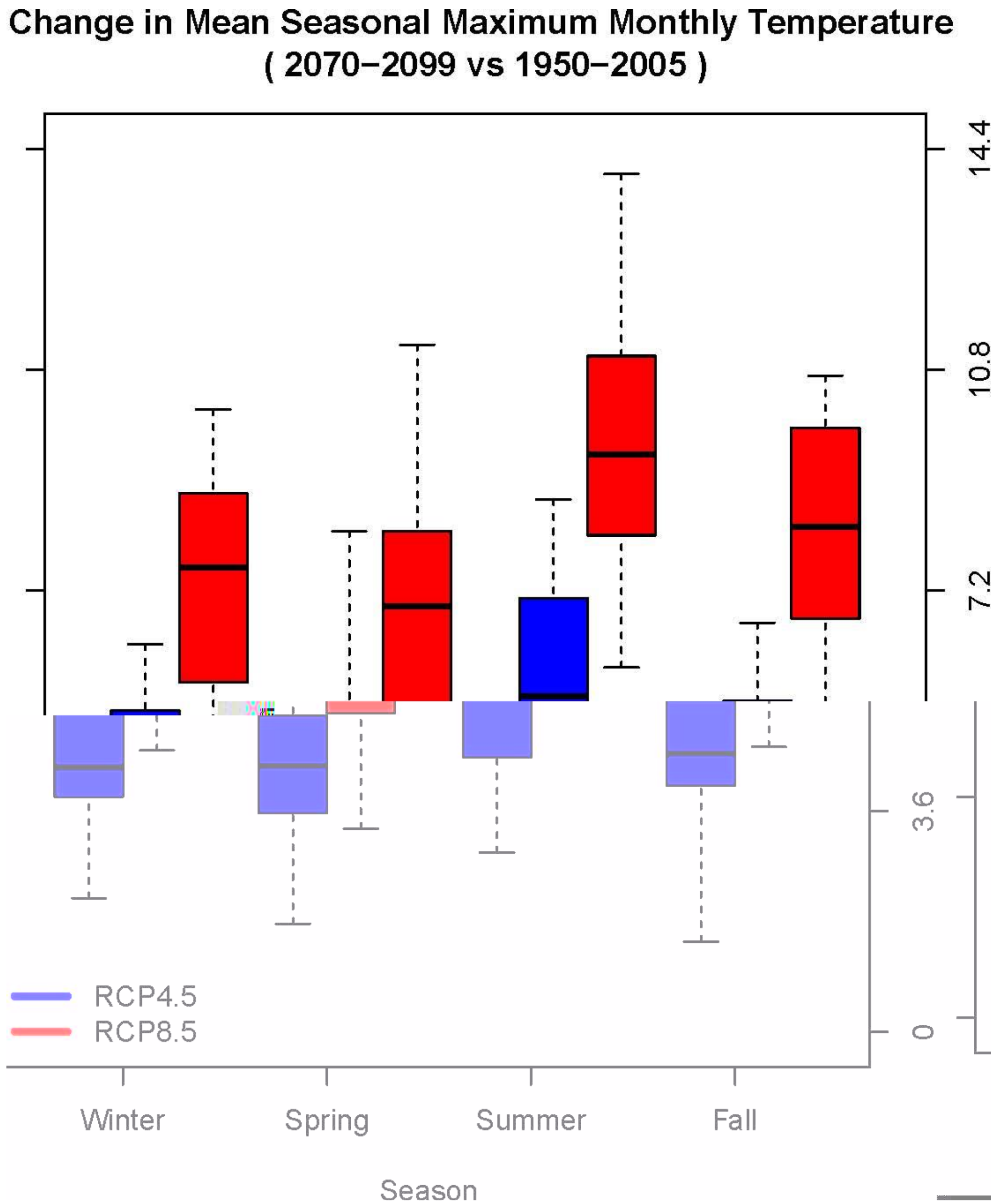

Change in Seasonal Mean Monthly Precipitation
(2040−2069 vs 1950−2005)
20
0
−20
−40
−60
%
RCP4.5
RCP8.5
Winter
Spring
Summer
Fall
Season


Change in Mean Seasonal Maximum Monthly Temperature
(2040−2069 vs 1950−2005)
14.4
10.8
7.2
3.6
0
RCP4.5
RCP8.5
Winter
Spring
Summer
Fall
Season

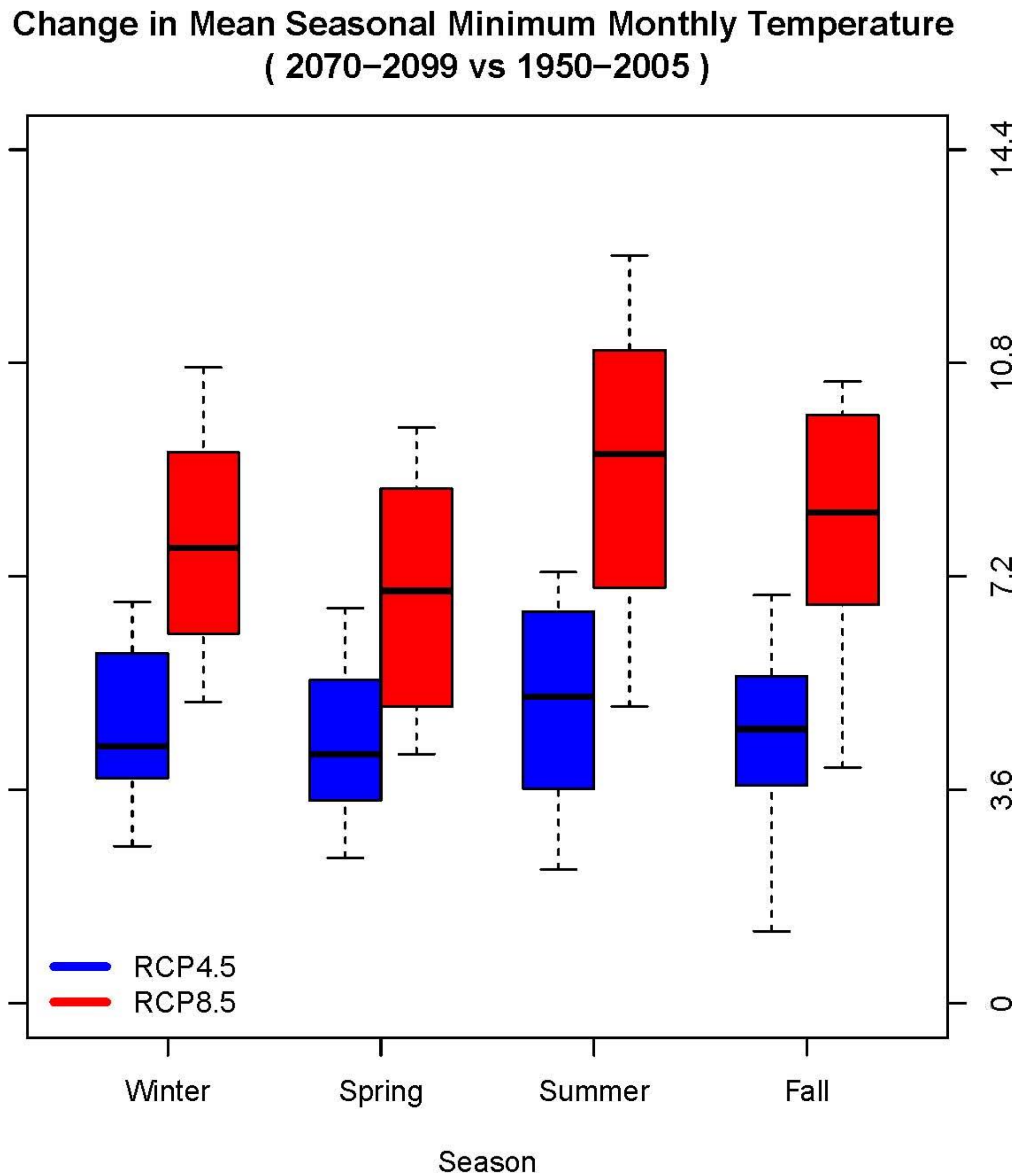

Change in Mean Seasonal Minimum Monthly Temperature
(2040−2069 vs 1950−2005)
14.4
10.8
7.2
3.6
0
RCP4.5
RCP8.5
Winter
Spring
Summer
Fall
Season

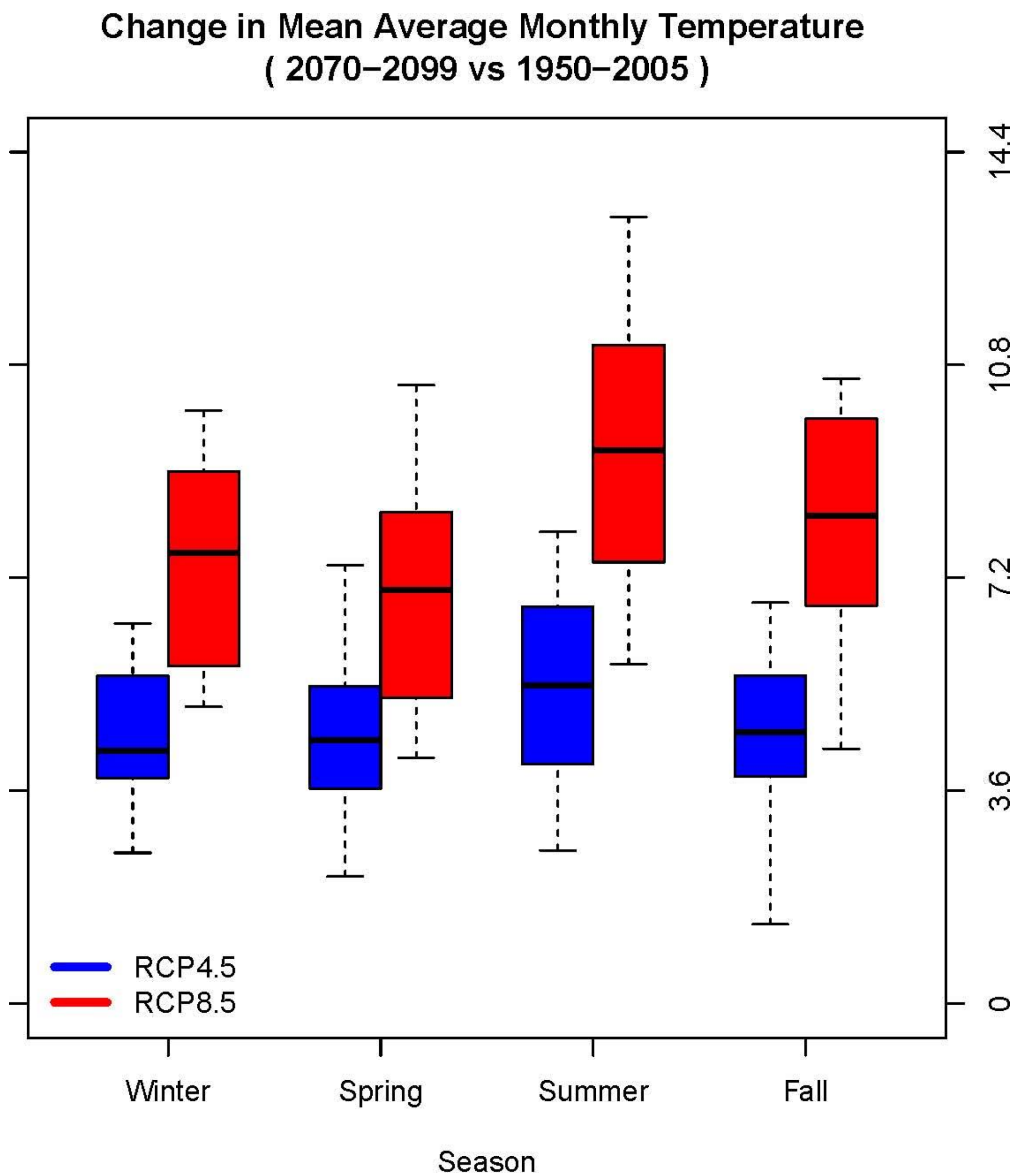

Change in Mean Average Monthly Temperature
(2040−2069 vs 1950−2005)
14.4
10.8
7.2
3.6
0
RCP4.5
RCP8.5
Winter
Spring
Summer
Fall
Season


Change in Seasonal Mean Monthly Precipitation
(2070−2099 vs 1950−2005)
%
20
0
−20
−40
−60
RCP4.5
RCP8.5
Winter
Spring
Summer
Fall
Season



Change in Mean Seasonal Maximum Monthly Temperature
(2070−2099 vs 1950−2005)
14.4
10.8
7.2
3.6
0
RCP4.5
RCP8.5
Winter
Spring
Summer
Fall
Season


Change in Mean Seasonal Minimum Monthly Temperature
(2070−2099 vs 1950−2005)
14.4
10.8
7.2
3.6
0
RCP4.5
RCP8.5
Winter
Spring
Summer
Fall
Season


Change in Mean Average Monthly Temperature
(2070−2099 vs 1950−2005)
14.4
10.8
7.2
3.6
0
RCP4.5
RCP8.5
Winter
Spring
Summer
Fall
Season